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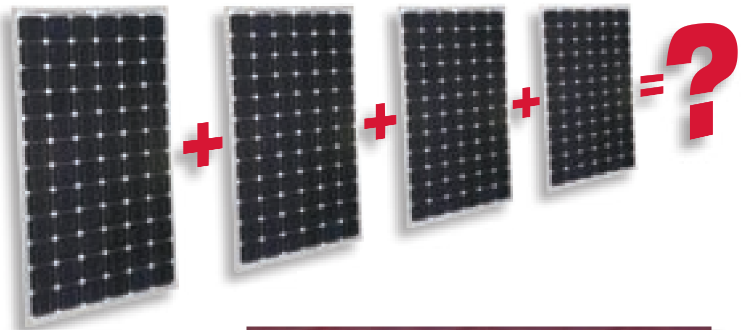
On the Cover

Mike and Joanne Young take renewable energy to the seas, using a small wind turbine and a PV system to meet most of their onboard electricity needs.

Photo by Roger Webb



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from us *to you*

GETTING A GRIP ON THE GRID

In the early days of the magazine, *Home Power's* goal was to network a fledgling off-grid solar movement. Our efforts created an ongoing information exchange that helped build the foundation of today's solar industry. About a decade ago, our focus shifted to bringing these proven technologies out of the backwoods and into backyards by sharing information on the latest in grid-tied solar-electric systems. After all, the vast majority of Americans live on grid, and in this wired realm, the potential for solar energy borders on limitlessness.

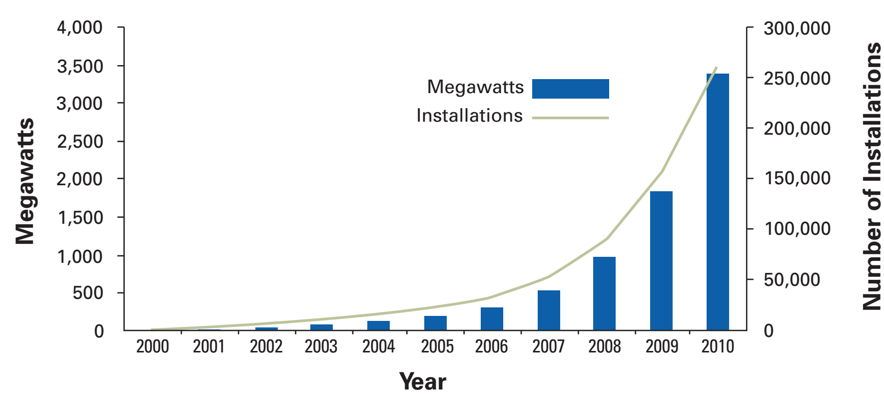
But where bringing the benefits of RE to off-gridders has been straightforward, interfacing solar technologies with the utility grid has been anything but simple. Some issues have been technical, but many have been related to policy, legislation, incentives, administration, and straight-out education about the impacts of PV technology on the grid-tied world. Just like in the early days, increasing communication between experienced and inexperienced users was key.

Along these lines, a recent report (www.solarelectricpower.org) published by the Solar Electric Power Association and the Interstate Renewable Energy Council caught my attention—and my imagination. The report was based on a survey of utility practices related to residential-scale grid-tied PV. "Several utilities reported thousands of PV systems. But the majority of utilities have not yet reached critical mass," said Mike Taylor, SEPA director of research. One of the conclusions drawn in the report is that solar-experienced utilities could assist utilities with little or no experience with small-scale distributed generation.

The concept of experienced utilities helping inexperienced utilities smooth the way for future PV installations is a fascinating indication of the momentum that's been created. And looking at what's coming down the pike, it's a necessary development. In the United States, installed PV capacity grew by 60%—101 megawatts—between 2005 and 2006. As impressive as these figures are, a *five-fold* increase in domestic PV capacity and the number of installations is projected over the next three to four years.

Advances in equipment design and system installation are guaranteed in today's competitive RE market, but information exchange, as pivotal as it is, isn't. If you have RE experience, share it. In many cases, it's the most powerful thing you can do to change the way we generate energy in the United States and beyond.

—Joe Schwartz for the *Home Power* crew



Cumulative Current & Forecasted U.S. PV Installations & Installed Capacity

Source: Larry Sherwood, IREC (2000–2006 data); Travis Bradford, Prometheus Institute (MW projections); Mike Taylor, SEPA (number of installation projections)

Think About It...

"Information's pretty thin stuff unless mixed with experience."

—Clarence Day

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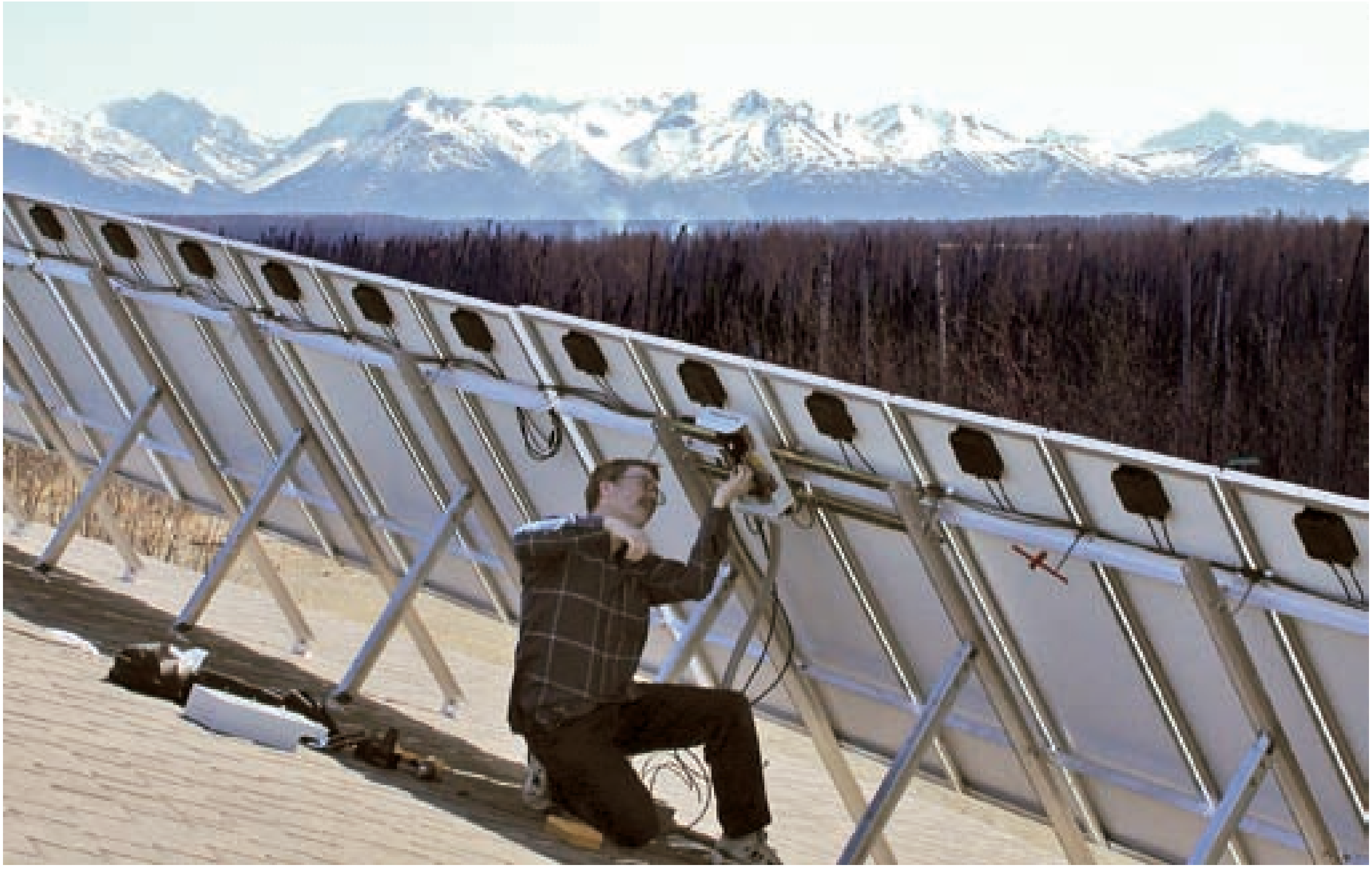
Ask the EXPERTS!



Courtesy remotepowerinc.com

Alaska Solar

I live on-grid in Anchorage, Alaska, and I'd like to install solar-electric modules on my roof. However, most of the information I can gather discourages their use in this climate.

I'm willing to use conventionally generated electricity in the winter, but in the summer, I'm sure there must be a way for me to rely solely on solar-generated electricity. Anchorage also doesn't get as much rainfall as the southeastern region of the state, and in summer, we receive 18 to 19 hours of daylight. Can you make any suggestions for the type of system that would be economically feasible for me to install?

Ann Pence • Anchorage, Alaska

Peak Sun-Hours Compared

Location	Avg. Daily Peak Sun-Hours* Jan.	Jul.	Annual
Anchorage, AK	1.0	4.4	3.0
Seattle, WA	1.6	5.7	3.7
Los Angeles, CA	4.4	6.6	5.6

*Fixed array, oriented to true south, tilt = latitude

It's a fact that Alaska in general doesn't get as much solar radiation as most locations in the southern 48 states. Still, if you installed a 700-watt array at a really good site, you could expect to generate at least 550 KWH per year (per the solar performance calculator at http://rredc.nrel.gov/solar/codes_algs/PVWATTS/). A ballpark cost would be $6,000 to $8,000 installed, and would qualify you for a $2,000 federal tax credit if your system was installed this year.

Unfortunately, the utilities serving Anchorage don't currently allow net metering or offer any incentives. This means they would pay at an "avoided cost" rate for electricity your system sends to the grid in excess of your usage between meter readings. Avoided cost is typically 4 to 8 cents per KWH, but may be less.

In Fairbanks, Golden Valley Electric Association started an incentive program called SNAP (Sustainable Natural Alternative Power) about two years ago. Based on the original SNAP program started in Chelan County, Washington, this program offers up to $1.50 per KWH to local renewable electricity producers who sell electricity back to the grid.

Recently I heard that Chugach Electric in Anchorage and Homer Electric in Homer will be starting their own SNAP programs this year. You should contact your utility to see if any incentives are available now or will be in the future.

If it turns out that PV just isn't economical enough at this time, there are plenty of cost-effective energy-efficiency improvements that you could make to your home. Look into the Anchorage Department of Neighborhoods' Weatherization Program and the Cooperative Extension Service in Fairbanks. Both are awesome resources for information on energy-efficient living in Alaska.

Greg Egan, Remote Power Inc. •
Fairbanks, Alaska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Courtesy www.iesolar.com (2)

Roof Replacement

I'd like to go into the business of installing rooftop solar energy systems on newly constructed buildings, but I'm concerned about the problem of roof replacement twenty years down the road. I can see a major disruption to PV modules and solar thermal collectors during reroofing. Are there installation techniques that address this problem?

Fred Mocking • Skokie, Illinois

Since removal and reinstallation of roof-mounted solar equipment can be quite expensive, usually requiring more labor hours than the system originally took to install, the frequency of possible roof replacement definitely needs to be considered. With new construction, the first thing is to start with a durable roofing material that has the longest life span you can afford. If you can install a roof that will last 30 to 40 years (or more), its longevity will be right in line with that of your solar energy system.

When it comes to purchasing a mounting system, I prefer to use round-style mounting posts, which mount on the roof decking, instead of feet made of angle stock (L-shaped mounting feet), which mount on top of the roofing. Round posts are flashed and roofed around just like a normal pipe vent. When it's time to remove and then reinstall the system for a new roof, you don't have to remove the mounting feet themselves, just the roofing material around them. If you're replacing the roof and have used angle-stock style mounting feet, you'll have to remove all the feet and will have to install your PV array or solar hot water collectors from scratch after the new roof is in place. Compared to angle-stock style mounting feet, round, flashed mounting feet will likely be more watertight in the long run.

Roofs in general are not intended to be walked on. Installing solar energy systems can result in substantial foot traffic on roofs, and even new roofs can be damaged during this process, taking valuable years off the life span of the roofing material. This is an especially important consideration with composition (asphalt) shingle roofs. On hot days, the asphalt will soften, making the shingles more vulnerable to damage. If you must work on the roof during hot weather, wear flat, soft-soled shoes instead of raised-heel work boots to avoid damage.

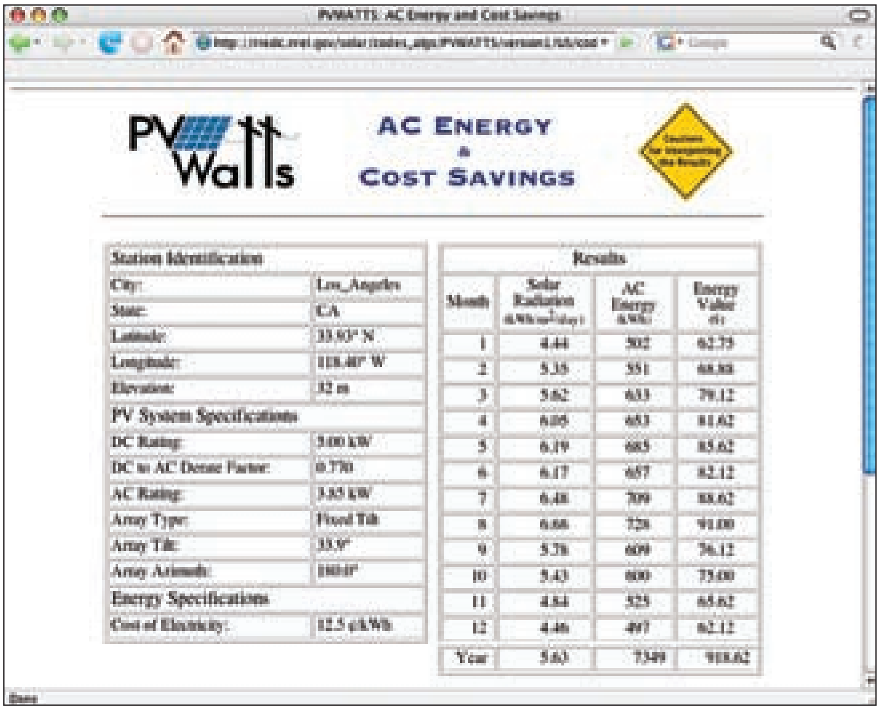
In all you do, remember to make safety your first priority—working on roofs puts you at risk for serious fall hazards. Don't forget to install permanent safety anchors when the new roof is going on, and use harnesses and fall protection gear while installing systems. Good luck, and work safe.

Kristopher Sutton, Sutton Solar • Paonia, Colorado

Off Grid or Not?

I'm shopping for rural property, and have looked at some parcels that are off the grid—some a short distance from utility lines and some a very long way. I don't know a lot about solar- and wind-electric systems, and hope you can give me some guidelines to help compare the cost of installing and owning a system with the cost of utility line extension. When is staying off grid—or connecting to the utility—worth it?

Pete Little • Los Angeles, California



One of the main financial advantages to off-grid living is the lower cost of land. But if you want electricity at your remote property, be prepared to pay. Whether your money goes to a stand-alone RE system or to the utility to bring in a line will be up to you and what your end goals are. In some areas, the expense of line extension will be prohibitive, making your decision to stay off grid easier. But if connecting to the utility grid costs $5,000 or $10,000, your decision may be a little more difficult.

Your first step should be to examine your motivations and goals. While many people dream of being off grid, they often are not aware of the responsibilities and ongoing costs. In most places, utility electricity is inexpensive compared to making your own electricity off grid, and when there's any maintenance or troubleshooting, you just call the utility. Off-grid system owners must be prepared to take on the utility's job, or pay someone else to do it.

So just how expensive is a residential off-grid electrical system? This depends on several factors, including incentives, the renewable resources available, and local installer pricing. But the biggest factor is the one only you can answer—how much electrical energy do you need? Here are some ballpark figures, and the resources to do your own analysis.

According to a Lawrence Berkeley National Laboratory study, the average house in your utility's service area used 5,900 KWH per year in 1999. Consider the cost of powering that average home with a PV system.

Using the PV output calculator (http://rredc.nrel.gov/solar/codes_algs/PVWATTS/), with default settings for Los Angeles, a system of 5 KW peak can meet the *annual* need, but you'll have 47% more energy available in August than in December. Most off-gridders do not try to size their system to provide all of their electricity in the winter; instead they rely on a backup generator to make up for reduced solar electricity generation. This hypothetical homeowner may buy a smaller system that meets demand for a portion of the year, and rely more on the engine generator during the winter.

As a very rough approximation, I use a total installed system cost of $12,000 per KW peak for an off-grid solar system. So powering the average home in southern California would require an investment of about $60,000! Some incentives may apply, but few are applicable to off-grid systems (see www.dsireusa.org).

Fortunately, most off-grid homeowners manage to live well using much less electricity than the average homeowner. This is accomplished with a mix of energy shifting (using gas or propane instead of electricity), efficiency (Energy Star appliances and compact fluorescent lighting), and conservation (turning off lights, no central air conditioning, etc.). As a result, many off-grid households manage with a PV system that produces about 1,500 KWH per year. In California, this would correspond to a system of about 1 KW peak, or $12,000.

If your site is blessed with a good average wind speed or a flowing creek, a hybrid system is likely to cost less than an all-PV system. But the output of a wind or hydro system is very site specific, so I can't be more exact.

The lack of utility access can save you money when buying land, perhaps enough to pay for your off-grid electric system, but you're wise to "run the numbers" before you buy.

John Richter,
Institute for Sustainable Energy Education •
Bingham Farms, Michigan

Solar Radiator

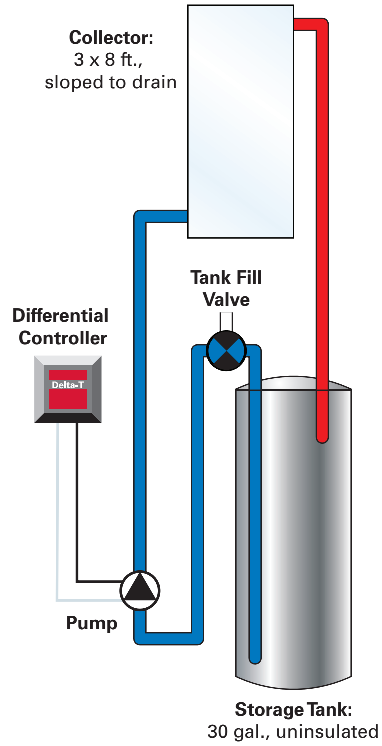
I want to use a 3- by 8-foot solar water-heating collector connected to a radiator to help heat an 8- by 10-foot room in my basement. If the water can reach temperatures between 140°F and 150°F, it should be hot enough to serve this function. Then, it's just a question of which type of radiator to use. I was thinking of using a standard baseboard heater or maybe an old cast-iron radiator. Then I thought about the advantages of using a thermal heat-storage "block" made of bricks. Hot water from the collector could be circulated through the block, which would absorb and slowly reradiate the heat. What do you think?

Paul Melanson • Nova Scotia, Canada

Your best bet for passive radiation is a baseboard element. Cast-iron radiators were designed for steam heat—they'll work with hot water, but not as effectively as a baseboard element. It is much more effective to use water as a storage medium than masonry block, because its specific heat (heat content) is about five times that of brick's specific heat.

If you don't mind the cosmetic appearance, a solar collector heating an uninsulated steel tank will make up a low-cost system. Make the system a drainback system and you'll just have four components—tank, pump, control, and collector. From a quick glance at the sunlight available in Nova Scotia, a 3- by 8-foot collector probably won't heat more than a 30-gallon tank in the winter. The beauty of this system is its simplicity and the fact that the tank keeps adding positive heat to the room down to 60°F or so.

Chuck Marken, AAA Solar • Albuquerque, New Mexico



RE Family

While my wife and I are interested in using energy more efficiently, and saving money doing it, I'm the one more interested in things like solar electricity and solar hot water. While saving money is an incentive, I'd like some advice from *Home Power* or from other readers on how they discussed moving toward a more renewable lifestyle with a spouse or significant other who isn't quite as motivated.

R. Tomaro • via e-mail


Josh Root

When my husband Lance and I first got together, we were already pretty well in agreement that we needed to take care of our own little corner of Earth. Over the years, we've had long conversations about our consumer society, and why we feel we need to do something personally. Well, we are still discussing that one 17 years later, and the list of what we plan to do comes out of our ongoing conversation! So we're in agreement about the direction we want to go, and we respect each other's reasons.

You two seem to be in agreement that it's important to try to live more responsibly. That's significant, and it's a great starting point for conversations. Each of you notices different symptoms of the unsustainable direction our society is tending, and you can share your observations as you gradually make your own decisions about what steps to take in your lives.

Now the only question is, how do you choose to go about it? People will order their lists differently, but assuming that your spouse agrees with you about the big picture, maybe it's just a question of what measures to start with. How about starting with some smaller things that can have a big impact, like weatherization or energy-efficiency upgrades? Maybe a more resource- and people-friendly yard? For ideas, check out the local solar tour of homes in your area (www.nationalsolartour.org). If you have kids, get them involved in the decision-making process. When your spouse and children see how pleasant this money-and-resource saving can be, they will eventually want to take the bigger steps.

Jennifer Barker, EO Renew • John Day, Oregon

Debra Galandzy and Doug Horn implemented energy-efficiency measures and installed a solar-electric system at their Vancouver, British Columbia, home.

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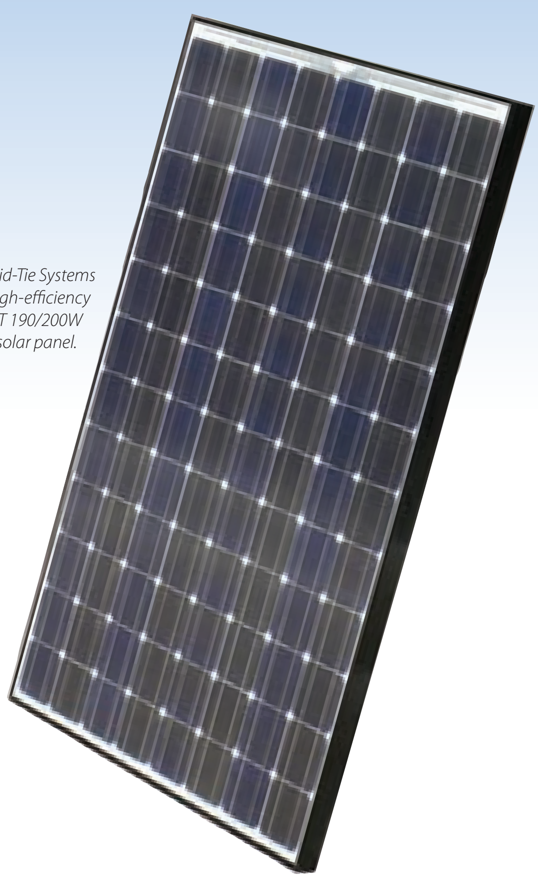

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Mailbox

A Better Hydro Intake

I was disappointed not to see a simple, in-stream intake included in Jerry Ostermeier's otherwise excellent article in *HP124.* Using the Hydro-Shear Coanda effect screen from Hydroscreen, I've installed simple, in-stream intakes multiple times, by choosing a suitable spot in the stream, and either building or inserting a screen box. Though these screens weren't originally designed to be submerged, my experience is that they work very well in this configuration if a vent is included lower on the penstock to release trapped air.

I've used 1 square foot of the screen to collect more than 100 gallons per minute (gpm), which covers many home-scale systems' needs. (The manufacturer claims it can collect 225 gpm per square foot.) By avoiding building a dam, we not only reduce the embodied energy in a hydro installation and minimize the impact on the streambed, we also keep the impact on the stream flow to a minimum, and don't impede fish. One of my intakes is so well hidden that the house sitter couldn't find it, even when he knew it was there.

I installed one that I only visit once a year for maintenance checkups. I've found that the screens are very much self-cleaning. Sometimes sand or pine needles will partially slow the intake. The worst blockage I've seen was by algae growth in a sunny location. An occasional scrub with a brush solves that problem.

Screens well anchored to large rocks need very little concrete to make a robust intake that is immune to flash floods. The water doesn't have anything to oppose it, and just flows over the top.

Chris Soler, Soler Hydro-Electric • Bow, Washington

"I've installed simple, in-stream intakes multiple times, by choosing a suitable spot in the stream, and either building or inserting a screen box."

Skip the Politics

In your editorial, "Waiting for the Sun" in *HP123,* I noticed an anti-Bush, anti-Republican tone. I must be blunt and let you know I don't like that at all.

I don't care if you vote Democrat or Republican; I just don't like the magazine to be infused with any politics. I pay to subscribe for the sole purpose of improving our world, not to listen to your prejudices about what one party did to another and what one party has done for RE versus another. I don't need or want your help in looking at these issues. If I want editorials on which party did "better" than the other, countless magazines can give me that.

I don't want to read another boring, biased editorial. Please just stick to RE untouched by bias (yours or anyone else's), and let us read a magazine that helps get on with the job of RE. *Home Power* is about solutions. Your editorial was not about solutions. RE is about unity, not division. Your editorial was about division, not unity. Both parties share the blame for the mess we are in. Don't try to make it someone's fault when we all share the blame. It serves no purpose.

Robert Montgomery • via e-mail

"Both parties share the blame for the mess we are in. Don't try to make it someone's fault when we all share the blame."

Hybrid Footprint

In regards to the article "Plug-in Hybrids" in *HP121*, the author points out that it is more economical to drive a vehicle with batteries recharged with utility electricity than to drive a gas-consuming vehicle. But being more economical does not mean you have a smaller carbon footprint or that you're burning less primary fuel (usually combustible fossil fuel). Because of inefficiencies in heat engines and distribution losses, typically only about one-third of the energy in a combustible fuel is turned into electrical energy.

The article states that 1 gallon of gasoline is equivalent to 34 KWH of electricity. In practice, 1 gallon of combusted gasoline will produce 11 KWH of electricity, not 34 KWH. One of the comparisons the article makes is between an electric car and a hybrid Prius. In the author's comparison, an electric car can travel 110 miles on 34 KWH, assuming 34 KWH is the amount of heat energy in a gallon of gasoline. But typically only one-third of this energy can be converted to electricity. The electric vehicle's mileage is then 110 divided by 3, or 36.6 miles per gallon. The author points out that the Prius at 50 miles per gallon costs twice as much to operate per mile.

With the author's assumption that most of the electricity generated in the United States is produced using fossil fuels, the Prius will consume 35% less primary energy than the electric car. However, because of the price structure, the electric car will cost less to operate.

The amount of carbon put into the air while generating electricity will depend on the type of fossil fuel consumed at the power plant. Per unit of energy, coal produces 66% more carbon dioxide (CO_2) than gasoline, and natural gas produces 20% less. The article points out that half of our electricity comes from coal. If more of our electricity is produced by renewables, the primary energy consumption and carbon footprint will be reduced for the electric car.

One reason for an electric car's economic advantage is that there are fewer taxes on electricity than gasoline. As a consequence, taxes will go up someplace else to pay for our roads. In the article on my house in *HP112*, this point is discussed further in regards to gas and electricity consumption for a home. For a home generating more electricity than it consumes, the article looks at the relative merits of feeding this electricity into the grid or using the excess electricity to reduce natural gas consumption. In California, if you generate more electricity than you consume on a yearly basis, you are not paid for the excess electricity you feed into the grid. In my home, I decided to feed my excess electricity into the grid. This further reduced my carbon footprint but resulted in a larger utility bill. My point is that the price structure does not always encourage the most efficient way to consume energy.

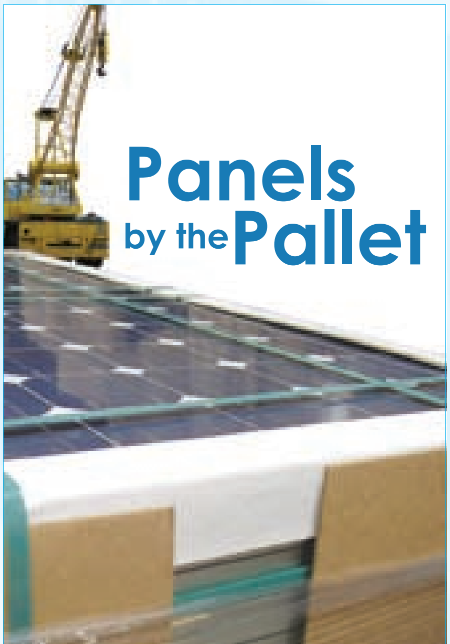
Larry Schlussler, Sun Frost • Arcata, California

The efficiencies of creating electricity depends on the generator used. A large-scale power plant will be more efficient than a small engine. According to the U.S. Department of Energy, well-to-wheel efficiencies (including *all* transition stages, from raw materials to motive power at the drive wheels) are 11% for gasoline-fueled vehicles versus 17% for electric vehicles. So whatever portion of its energy a plug-in hybrid took from the grid would be half again as efficient as the gasoline burned in an internal combustion engine (ICE) vehicle.

If you are going to look at the carbon footprint of the grid-supplied electricity of the plug-in hybrid and include the power plant, then you will also need to include the carbon footprint of the gas refinery in your calculations for an ICE car, as well as the tanker trucks that deliver it. Keep in mind that gas refineries use an enormous amount of electricity, so some carbon impact from the electric power plant would have to be applied to the ICE vehicle as well. It is inherently more efficient to use the electricity to directly power a vehicle than to power a gas refinery to make gasoline to power a vehicle.

The scale for greater efficiency (therefore, lower pollution and carbon footprint) proceeds in this order: gas vehicles to hybrids to plug-in hybrids to grid-charged pure EVs to renewable-energy-charged pure EVs.

Shari Prange, Electro Automotive • Felton, California



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ES-180, 180w, 16v, Pallet of 30

KYOCERA

KD180GX-LP, 180w, 16v, Pallet of 20

SHARP

ND-216U2, 216w, 16v, Pallet of 28

SUNTECH

STP170S-24Ab-1, 170w, 24v, Pallet of 44

Supplies are limited.

Pallet quantity varies by manufacturer, please call us for more details. If there is another panel that interests you but it's not listed here, please contact us.

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KACO 1kW

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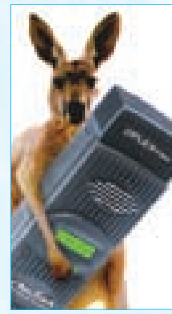
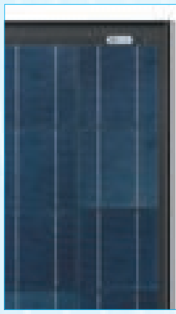


OutBack FLEXmax 80

Charge Controller

The FLEXmax 80 is the latest innovation in Maximum Power Point Tracking (MPPT) charge controllers from OutBack Power Systems.

Our Price : $ 580.00



BP Solar SX3200B

200 Watt 16 Volt PV Module

High-efficiency photovoltaic module using silicon nitride multicrystalline silicon cells.

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SMA SB 7000US

7000 watt inverter

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Air-X Land 24V

Wind Turbine Kit

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Hybrid Heating System

As a person who has worked in the HVAC industry my entire life, I found your article, "Home Heating Options," in *HP123* both accurate and informative. One option that you did not suggest, much to my surprise, was the hybrid gas furnace/air-source heat-pump system.

Even in my home state of Wisconsin, where the winters are extremely cold, a hybrid system is a real energy saver and has a very reasonable payback. Standard air-source heat pumps are effective for home heating with outdoor temperatures down to 20°F, depending on the moisture content in the air. I installed a heat pump as a companion to my more than 90% efficient propane furnace two years ago and have documented overall energy savings in the 25% to 30% range. A dual-fuel controller operates the furnace automatically when it is too cold for the heat pump to be effective. Using this combination, my propane furnace did not come on until December and did not operate after mid-February, since the temperatures were above 24°F—the system's changeover point—the majority of the time. On many days during the winter, the furnace would run early in the morning and the heat pump would take over as the daytime temperature rose. My heat pump is a standard 11 SEER, R-22 unit. Newer units coming onto the market will offer better efficiency and better heat transfer at low temperatures.

My 2,200-square-foot home has some passive solar gain, and I am careful about setting back the thermostat. With the new system, over the past 12 months, I have paid an average of $100 per month for propane and $120 per month for electricity, including heating or air conditioning. This is with propane at $2.25 per gallon, and electricity at about $0.095 per KWH. I also installed a Bosch tankless water heater, which has contributed to my energy savings.

I enjoy your magazine a great deal and have gained much knowledge about renewable energy, which I plan to incorporate into the next home I build. Keep up the good work. I will look for an article on hybrid heating systems in the future.

Mike Henry • Edgerton, Wisconsin

"I installed a heat pump as a companion to my more than 90% efficient propane furnace two years ago, and have documented overall energy savings in the 25% to 30% range."

Moving Toward Energy Efficiency

I just discovered your magazine at the library today and was excited to see another source of information regarding building an energy-efficient home.

We are hoping to sell our house soon. I am being threatened with legal action if I hang my clothes on a clothesline (see *The Wall Street Journal*, September 18, 2007).

One thing led to another, and we decided rural living is more conducive to our lifestyle. We feel this is an opportunity for us to build green *and* hang a clothesline without our neighbors complaining.

I look forward to getting great ideas for building a new house from your magazine. In the meantime, encourage your readers to hang their clothes out on clotheslines to dry. Clothes dried in the fresh air smell great, and you can save up to 10% of residential energy use by not using your dryer.

Susan Taylor • Bend, Oregon

Errata

In the wiring schematic on page 53 of *HP124* we overlooked the positive grounding requirements of the SunPower PV modules. The positive (grounded) conductors should be white. The negative (ungrounded) conductors should be black in this configuration, and routed through the array disconnect switch. The correct wiring configuration is shown below.

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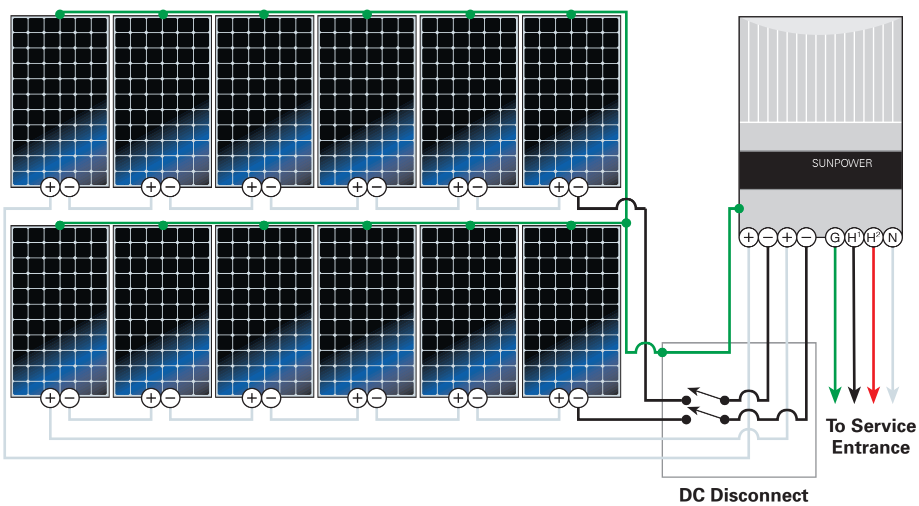


Off Grid & Off Shore

by Derek Young
photos by Roger Webb

Some say home is where you hang your hat. Michael and Joanne Young say home is where you hang your PV modules—and your wind genny. As they have found, you can travel and have all the comforts of home by bringing along your own power company.

When Mike Young imagined his dream home, his fantasy included one mast, two sails, a wind turbine, and a solar-electric system. "I pictured my wife and myself on a sailboat surrounded by blue water. I saw us enjoying sunrises and sunsets day after day, breathing in the salt air while listening to the ocean and watching the sails fill with wind," says Mike, a native of Springfield, Vermont. "I saw us living independently."

Fed up with Vermont's cold, dark winters, Mike fell in love with the idea of escaping to the warm, sunny Caribbean for part of the year. An avid sailor who spent many years sailing on Lake Champlain and crewing on friends' boats, he had the know-how to pull it off. All he needed was an ocean-worthy vessel and a good first mate. "When he first told me the idea, I thought he was crazy," says Joanne, his wife of 40 years. "But he was serious."

The couple bought *Orion*—a 37-foot sloop—and upgraded its navigational, steering, and safety systems for ocean cruising. They sold the family's retail propane business and embraced the idea of early retirement at age 52. In 2000, Mike and Joanne made their maiden voyage to the Caribbean islands. From Shelburne, Vermont, they took *Orion* south to the Hudson River, which brought them to New York City. From there, they followed the coast south to Virginia, where they departed on the 11-day voyage to Virgin Gorda.

A noisy diesel engine used to spoil the ambiance at dinnertime. With their RE systems in place, Joanne and Mike now enjoy quiet evenings.

Testing the Waters

The first trip gave newbie cruisers Mike and Joanne the chance to get a feel for their energy needs. They left home with a diesel engine set up to charge a 12-volt, 366 amp-hour battery bank that powered the boat's electrical loads. Though the engine worked well for cruising when winds were low and produced more than enough energy for battery-charging, it was less than ideal for generating energy for their day-to-day needs—lighting, refrigeration, and hot water, and for small household appliances, the navigation equipment, and communication radios.

Running the engine a few hours each day to recharge the battery bank burns about 1 gallon of diesel fuel—only about 90 cents on the islands—so it wasn't the expense that bothered Mike and Joanne. It was the fumes and the noise. A diesel engine likes to be run hard and hot, preferably over long periods

Above: The inverter's remote monitor.

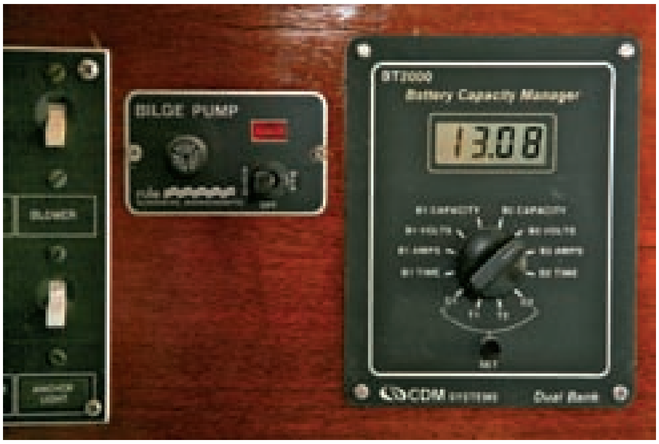
Left: Captain Mike with the *Orion*'s RE-powered navigation and communication gear.

Mike and Joanne's two-module PV system and wind generator have significantly reduced their reliance on the boat's diesel generator.

with a heavy load. But when it's used as a generator only, the engine doesn't operate at its optimal temperature and burns inefficiently, producing more pollution per energy output.

To add insult to injury, the warm Caribbean temperatures doubled the energy requirements of the refrigerator and freezer—two of the largest and most critical demands on the batteries. Because they wanted to avoid paying for electric hookups at marinas, Mike and Joanne found that they needed to run the engine at least twice a day—about an hour during the day and an hour at night—to charge the batteries and meet their electrical loads.

"Have you ever heard or smelled a diesel engine?" Mike says. "There was no room in my sailing fantasy for a smoky, noisy diesel engine and all its pollution. The engine ruined one too many cocktail hours on the deck. I looked around and saw other boats with solar modules and wind turbines, and knew what I had to do."



The battery monitor, conveniently located next to the other electric controls.

Sustainability at Sea

For cruisers, who generally sail in areas where the sun and wind are abundant, combining solar and wind power is a no-brainer—especially when the alternative is burning diesel fuel to charge batteries. "When you use the power of the wind to move your home," Mike says, "you feel good. And when you can power the rest of your needs with renewable energy, it completes the picture."

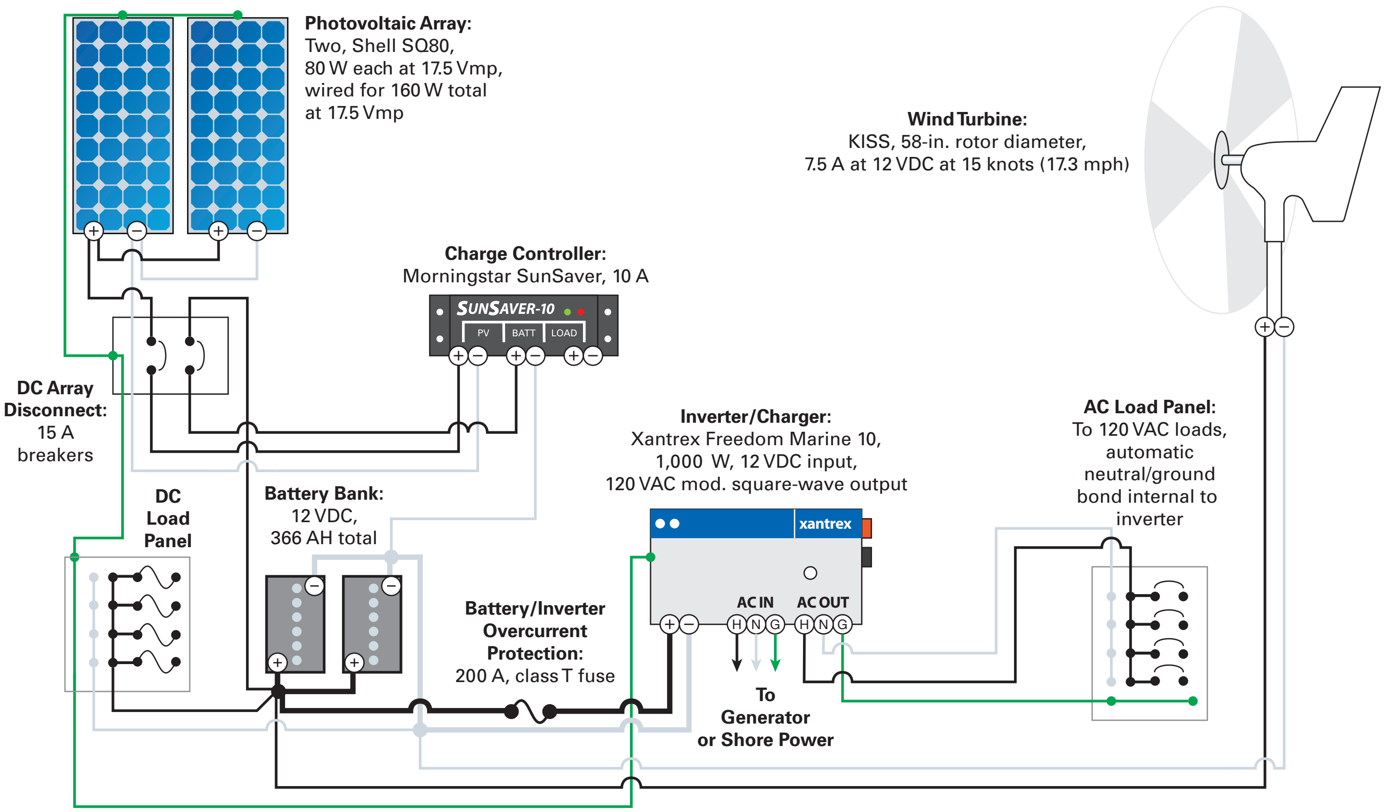
In 2003, after talking with fellow cruisers and observing different wind turbines at work, Mike purchased a wind turbine manufactured by Kiss Energy Systems (KES) in Chaguaramas, Trinidad. Designed for marine conditions, the KISS (Keep It Simple Sailor) turbine is durable yet quiet enough for the confined quarters of a sailboat. Elliptical blade ends minimize tip noise, while a 9-foot tower mounted to the stern provides plenty of headroom—nearly 7 feet.

Mike and Joanne saved on labor costs by installing the turbine themselves. Instead of using the mast mount kit offered by KES, they fashioned a mount from stainless-steel pipe—which cut costs some but added hours to the project. "Measuring, cutting, and fitting the turbine mount took several days. What made the installation more difficult was that we did it at anchor. It would have been much easier if the boat was on land or docked, but we managed," Mike says.

Three blades make up the 58-inch-diameter rotor. The aerodynamic fiberglass two-piece housing is hand-molded in KES's Chaguaramas shop, as are the blades. The manufacturing of the three-phase, permanent-magnet alternator is subcontracted to local fabricators. The alternator's three-phase AC output is, in turn, converted to DC for battery charging. In typical 15-knot (17.3 mph) winds, the turbine can produce up to 7.5 amps for the 12-volt nominal battery bank. If batteries are full, the wind genny can freewheel or an electrical brake can minimize the rotation in winds up to 30 knots (34.5 mph). Stronger winds require the freewheel mode, and a thermal switch reduces the output and prevents the alternator from overheating.

Because the turbine does not include additional regulation other than the thermal switch, manually furling the turbine is necessary to prevent excessive battery voltages. Mike does

Young Off-Grid PV & Wind System



Note: All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified.

PV & Wind Systems Tech Specs

Overview

System type: Battery-based solar- and wind-electric

Location: New England to Trinidad

Solar and wind resource: Varies with location

Photovoltaics

Modules: 2 Shell SQ80, 80 W STC, 17.5 Vmp

Array: Two modules in parallel, 160 W STC total, 17.5 Vmp

Array installation: Self-fabricated flush mounts made from stainless-steel tubing, installed horizontally over the boat's cockpit

Orientation: Varies with the movement of the boat

Wind Turbine

Turbine: KISS (Keep it Simple Sailor)

Rotor diameter: 58 in.

Rated energy output: 7.5 A, 12 VDC nominal, at 15 knots (17.3 mph)

Rated peak power output: 25 A at 12 VDC nominal

Mount: Home-built stainless-steel pipe, rubber-mounted on the stern

Energy Storage

Batteries: Two Deka 8G4DM, 12 VDC nominal, 183 AH, sealed gel

Battery bank: 12 VDC nominal, 366 AH total

Balance of System

Charge controller: Morningstar SunSaver, 10 A

Inverter: Xantrex Freedom Marine 10, 1,000 W, 12 VDC nominal input, 120 VAC modified square-wave output

Battery capacity metering: CDM Systems BT2000

Living the good life.

Because the position of the boat is always changing and shadows are inevitable, the placement of the modules is not critical to the system's overall performance. "On a boat, it's usually a matter of finding free space where the modules are out of the way and won't get damaged," says Mike, who chose not to tilt the modules, and instead, flush-mounted them to the bimini frame. "I probably could have gotten slightly better performance if I'd made the mount adjustable, but the sun is so strong and the days are so long here that the slight gain didn't seem all that important."

Off-Grid Self Sufficiency

"When traveling in remote places, you are forced to become a jack of all trades—an electrician, plumber, diesel mechanic, and handyman, all in one," Mike says. "My best defense is to be prepared for anything. I've done my research, and I can handle most repairs that arise. So far, so good."

Mindful of the elements, Mike took extra care when wiring both the wind- and solar-electric systems—twisting, taping, and heat-shrinking all connections. "The salt air can be brutal on mechanical systems of any kind," he says. "So long as the wire connections are sealed properly, then you have very few problems and the systems are easy—virtually maintenance free."

Well, almost…"There are a lot of seagulls, and we have to clean the droppings off the modules. If we're lucky enough to have fresh water, then we just hose off the modules now and again," he says. "But it's not so bad. I'll take bird droppings in the Caribbean over Vermont's snow and ice any day."

Thanks to their wind- and solar-electric systems, Mike and Joanne enjoy all the comforts and conveniences of home with cleaner, quieter power sources. "Solar does great in the daytime," Mike says, "but at night, when energy needs are much higher, the wind takes over." The sun is fairly

not worry too much about overcharging the batteries, since he's never far from the boat for long. On the rare occasion when the turbine needs a break or, in trade winds, makes too much noise, he stops the rotor manually by switch. "If we're lucky enough to make that much energy, it's time to do some ironing, use the microwave, or make some other use of it," he says.

Solar in Safe Harbor

"It's a double-edged sword with wind," Mike says. "We like the wind, and we need the wind, but we also like to get out of the wind." Before, anchoring in low-wind spots or seeking shelter in harbors meant that the couple had to rely on the diesel generator. For that reason, Mike chose to supplement the wind generator with a simple solar-electric system—two Shell 80-watt PV modules mounted horizontally on the bimini (awning) over the cockpit. He purchased the modules from Marine Warehouse in Trinidad, and sourced from a local hardware store the electrical cabling and other parts—stainless-steel tubing, mounting brackets, and nuts and bolts that resist the corrosive effects of salt water.

Indoor lighting and television, powered by renewable energy.

consistent, but when there is not adequate wind, Mike and Joanne still must offset energy usage by running the engine to charge the batteries. On its own, the solar-electric system produces about 55 amp-hours (AH) per day on average—shy of their 70-AH usage. "One more PV module, and we'd be perfect," Mike says. "I just need to make room for it."

Currently, the 12-gallon hot water tank is fitted with a heat exchanger that uses waste heat from the diesel engine to heat water for domestic use. When Mike and Joanne need to replenish the hot water, they run the engine, usually every third day for about an hour. Though the engine only burns about a half gallon of fuel—about 45 cents' worth—in that hour, that's one hour and one half gallon too much for Mike. He has devised a plan to add a custom solar hot water system off the stern. Tapping into the existing plumbing will be fairly easy, he says, but coordinating the shipping of the unit to the islands will require some patience. "This," he says, "is the last piece. Then we'll be totally independent."

On the Horizon

For the past eight years, Mike and Joanne have spent every winter island-hopping around the Caribbean. By living simply and relying on renewable energy, they keep their expenses down. They anchor at out-of-the-way places and catch their dinner most nights. One yellowfin tuna feeds the couple for days, and they trade what they can't store for other goods. Though the couple only saves an estimated $15 per week by offsetting their diesel fuel use, every dollar helps perpetuate their cruising lifestyle.

For the rest of the year, the couple returns to their home in Springfield, Vermont. "We have the best of both worlds right now," Joanne says. "When this all started, he had to drag me down here kicking and screaming, but now I love this lifestyle—seeing all the different places, meeting the local people, and hanging out with fellow cruisers. Living by the wind and the sun—I wouldn't have it any other way."

Access

Derek Young (seagoatmusic@gmail.com) is a freelance writer and musician who dabbles in renewable energy. He lives in a solar-powered camper in an undisclosed, off-grid location in Vermont.

System Components:

East Penn Manufacturing Co. • www.eastpenn-deka.com • Deka batteries

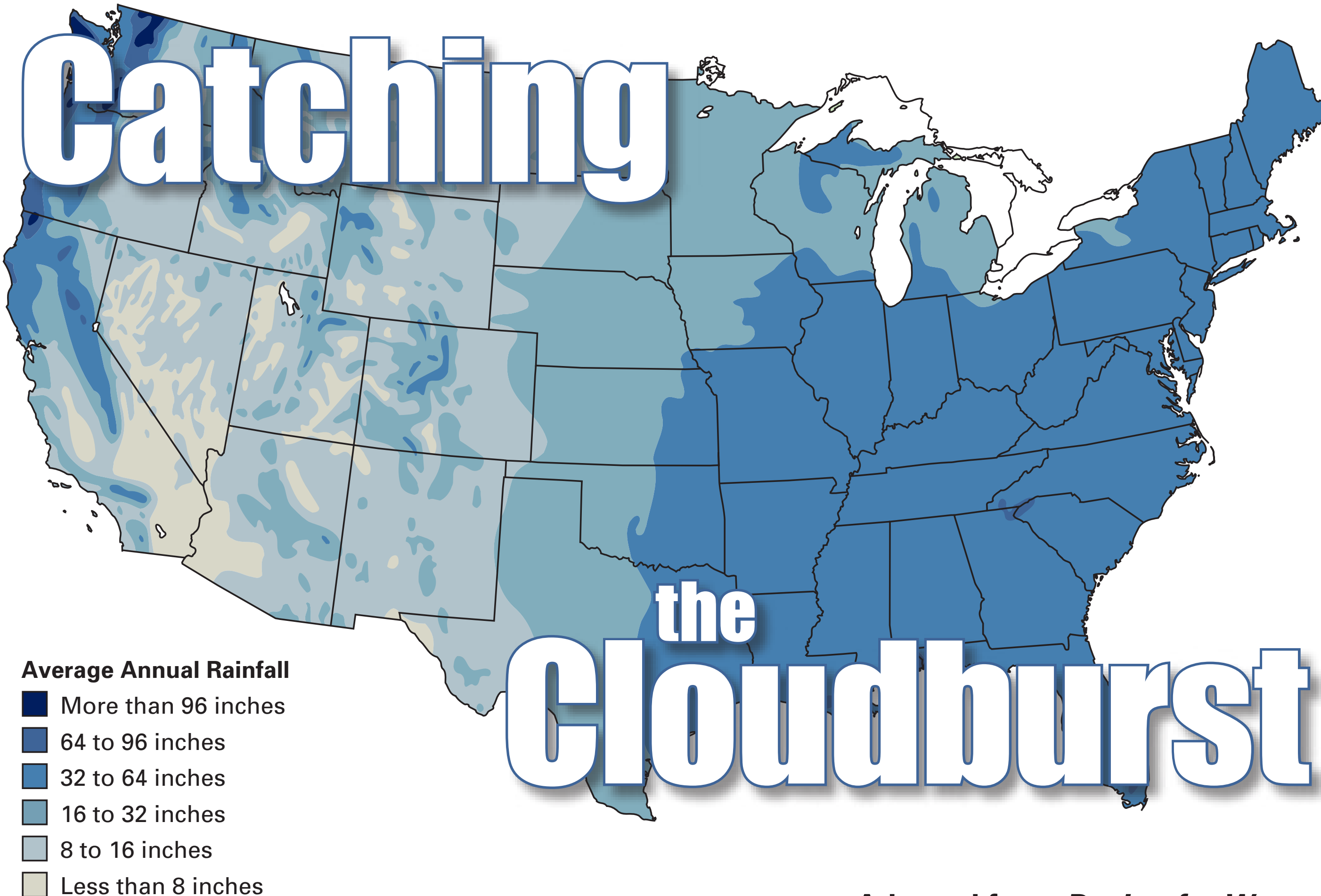
Kiss Energy Systems • www.kissenergy.com • Wind turbine

Morningstar • www.morningstarcorp.com • Controllers

SolarWorld • www.solarworld-usa.com • PV modules

Xantrex • www.xantrex.com • Inverter/charger

Catching the Cloudburst



Adapted from *Design for Water*
by Heather Kinkade

Like it or not, drought is becoming more common in many parts of the country. As dropping water levels in rivers and aquifers put the squeeze on freshwater stores, municipalities are tightening their belts, raising rates, and even implementing water-use restrictions. This past spring, Raleigh, North Carolina, residents and others in six surrounding towns were under "stage 2" water restrictions—no lawn sprinkling, no car washing, and no pool filling. Similar curbs are becoming more prevalent across the country.

Even those who rely on well water aren't escaping the consequences, as underground water tables drop below the reach of many wells. In 1999, a drought in the Northeast lowered water levels below their pumps in hundreds of wells in two New Jersey counties. Three years later, the prospect of parched wells pitted farmers against city dwellers of Cheyenne County, Nebraska, in an effort to secure water. And the situation is not getting better. According to a 2007 report by the U.S. Geological Survey, underground water supplies all over the United States are continuing to shrink.

Some people are looking to the skies: catching and storing rainwater. A rainwater harvesting system can reduce the need and cost to pump groundwater, and can be less expensive than tapping other water sources. It also provides a close-by water supply that contributes to self-sufficiency. Rainwater is "soft" water that's low in mineral content, which helps reduce buildup in your home's plumbing. In coastal areas where saltwater intrusion into aquifers is a problem, catchment becomes even more important. And, in some places, installing a rainwater system makes you eligible to receive rebates for reducing your use and dependency on municipal water.

System Components

Rooftop rainwater harvesting systems are easy to construct, operate, and maintain. Whether it is large or small, a rainwater harvesting system has six basic components:

1. Catchment area: The surface upon which the rain falls, generally a roof or impervious pavement.
2. Conveyance: The channels or pipes that transport the water from the catchment area to storage.
3. Roof washer: The systems that filter and remove contaminants and debris, includes first-flush devices.
4. Storage: The tanks where collected rainwater is stored.
5. Distribution: The system that delivers the rainwater for its end use, either by gravity or pump.
6. Purification: The equipment that filters and distills, as well as additives that filter and disinfect the collected rainwater.

Catchment Area

Although rainwater harvesting for nonpotable use can be accomplished with any type of roofing material, for potable use, the best roof materials are metal, clay, or concrete. Water for drinking purposes should not be collected from roofs containing zinc coatings, copper, asbestos sheets, lead, or asphalt compounds. For flat or semi-flat roofs, an acceptable roofing material for potable water catchment systems is Weather Barrier Raincoat 2000 (www.haleypaint.com), a coating product approved by the National Sanitation Foundation (NSF).

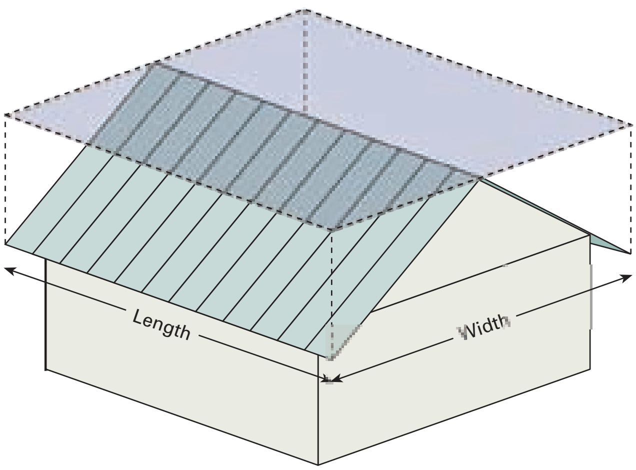
Rainwater Regs

Several communities are enacting regulations and guidelines for dealing with rainwater harvesting. In Arizona, the towns of Tucson, Flagstaff, Chino Valley, and Pason have enacted ordinances encouraging the use of harvested rainwater. In Washington state, Seattle and Friday Harbor, as well as King County, have recently established their own guidelines.

Currently, the American Rainwater Catchment Systems Association is working with several national organizations to come up with general ordinances that communities can revise and adopt. Texas has state legislation dealing with rainwater harvesting and, along with Hawaii and Virginia, offers rainwater harvesting guideline booklets (see Access).

The Uniform Plumbing Code has an appendix dedicated to rainwater systems, with sizing guidelines for gutters, downspouts, and lateral pipes. The applicable plumbing code should be reviewed for any design of rainwater conveyance systems.

Catchment Area



Length (ft.) x Width (ft.) x Annual Rainfall (in.) x Surface Area Efficiency x 7.48 gal./ft^3 = Annual Catchment Area Runoff (in gal.)

A *rainbarn* describes an open-air shed with a large roof area to catch rainwater. The structure can also provide shelter for a variety of uses—a patio, carport, hay storage, or farm equipment storage—thereby serving multiple functions. Typically, the rainwater storage cistern is housed under a rainbarn.

The quality of the captured rainwater depends, in part, upon catchment texture: The best water quality comes from smooth, impervious catchment or roofing materials. Quality is also determined by rainfall pattern and frequency. The greater the storm event (i.e. the rainfall extent) and the shorter the time between storms influence the cleanliness of the catchment area. Greater rainwater volumes and frequencies will transport fewer pollutants to the first-flush device and to storage.

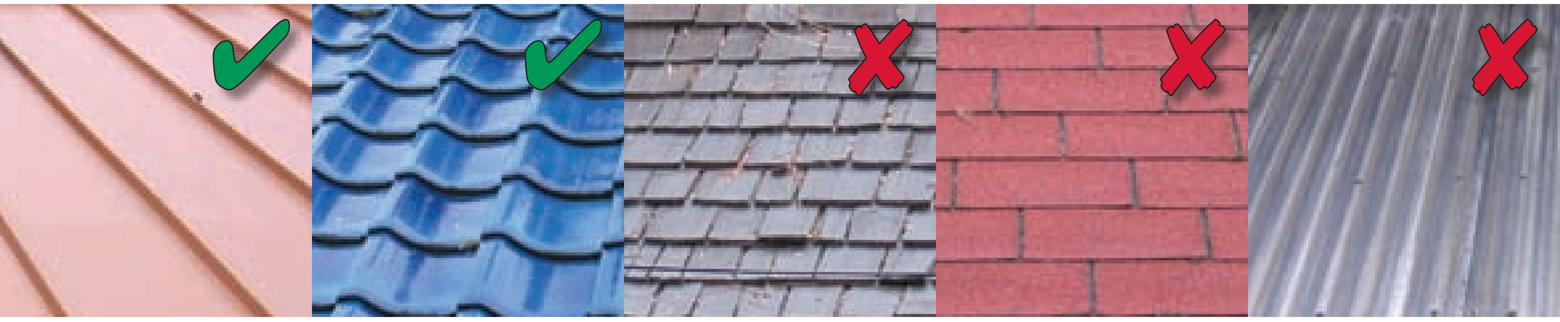
Rainwater is slightly acidic, which means it will dissolve and carry minerals into the storage system from any catchment surface. For systems intended for potable water, first test the water collected from the proposed catchment surface to determine its contents. In some cases, filtration can remove some contaminants. In other cases, the catchment surface must be reevaluated or amended.

Conveyance

A common rainwater conveyance system features gutters with downspouts that direct rain from rooftop catchment

Roof Surfaces for Potable Catchment

Yes—Painted metal | Yes—Ceramic or concrete | No—Wood shingles | No—Asphalt | No—Galvanized or copper



surfaces to cisterns or storage tanks. The materials for gutters and downspouts range from vinyl and galvanized steel to aluminum, copper, and stainless steel. At a minimum, gutters should be 5 or 6 inches wide, with an outer edge higher than the roof-side edge and splash guards at roof valleys. Gutters should slope toward downspouts at 1/16 to 1/4 inch per 10-foot length of gutter, and be installed per manufacturer's guidelines for hangers and connection points.

Downspouts should have 1 square inch of outlet (downspout) for every 100 square feet of roof area to be drained—a 4-inch-diameter downspout can drain approximately 400 square feet of roof area. Add more or larger downspouts for larger collection areas. A typical connection material from a downspout to a cistern is a 3- or 4-inch-diameter, schedule 40 PVC pipe or ABS pipe, which is considered a more environmentally friendly plastic. However, for potable rainwater collection, PVC or stainless steel should be used. It is made from new material, not recycled material that may have picked up contaminants from its previous use. Coated aluminum downspouts are also acceptable for potable water collecting. Avoid ABS, DWV PVC, copper, lead-containing, or galvanized pipes.

To keep leaves and other debris from entering the system, the gutters should have continuous leaf screens made out of 1/4-inch wire mesh or an equally efficient product covering the entire length of gutter. Installing leaf screens will help reduce system maintenance, reduce mosquito-breeding habitat, and eliminate the need for frequent ladder-climbing to clean the gutters. Downspout filtering rain heads, such as the Leaf Beater and the Leaf Eater, provide a second chance to capture and remove debris that might enter a storage system.

Courtesy www.guttersupply.com

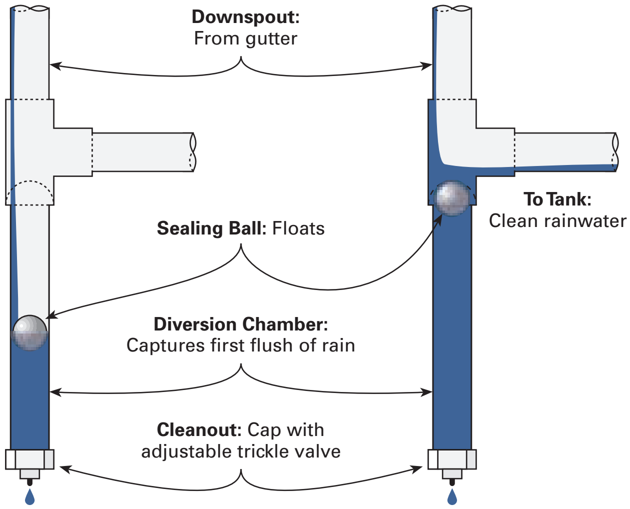
Leaf screens are the first defense in keeping debris out of your system.

What's a Rain Head?

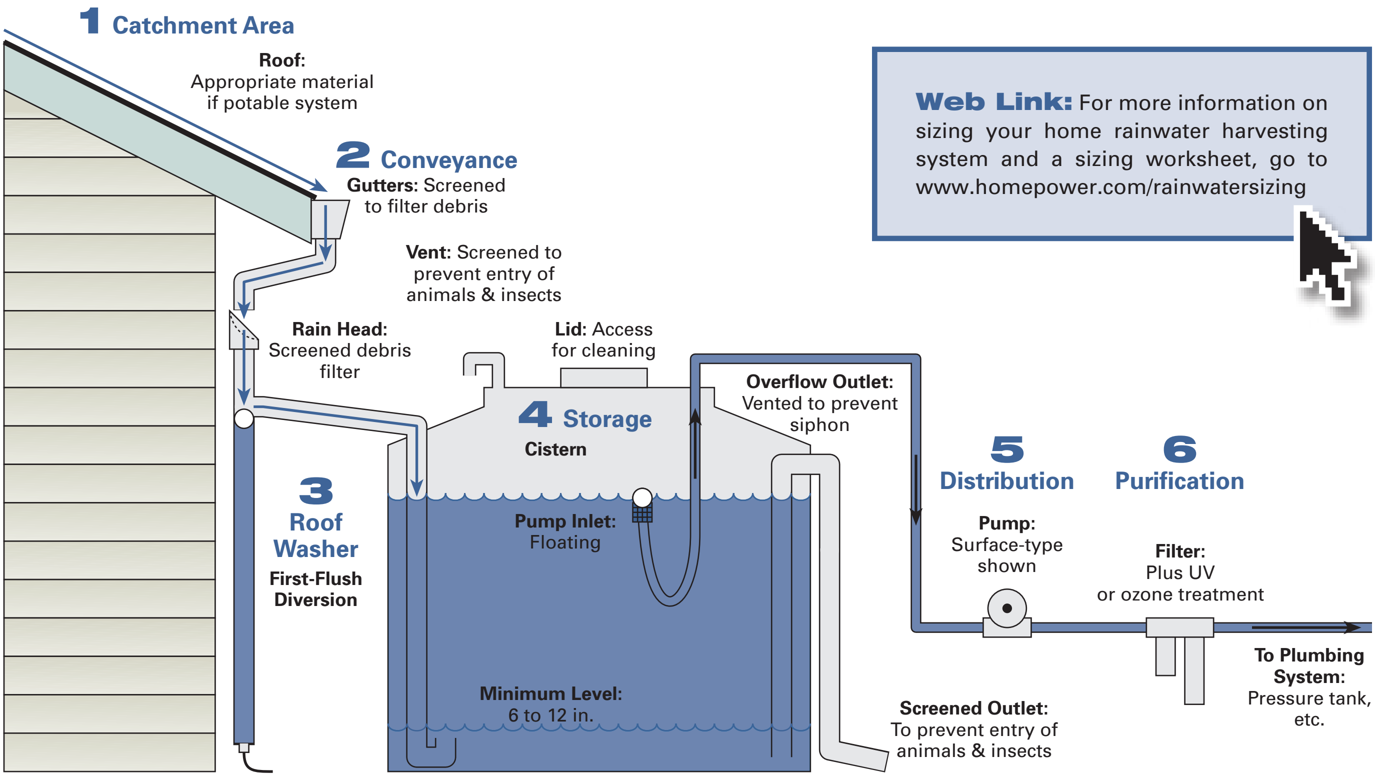
The filtering process can be augmented by using a rain head—a downspout that incorporates a self-cleaning system. This unit has a funnel topped by a screen, which is set at an angle of about 33 degrees to the lower horizontal edge of the funnel. As the water washes over the angled screen, the debris is forced toward the screen's lower edge and away from the building, while most of the rainwater continues through the funnel screen.

Courtesy www.rainharvesting.com

First-Flush Diversion



Basic Potable Rainwater Catchment System



Web Link: For more information on sizing your home rainwater harvesting system and a sizing worksheet, go to www.homepower.com/rainwatersizing

Roof Washing

Roofs, like other large, exposed areas, continuously receive deposits of debris, leaves, silt, and pollutants on their surfaces. One or several components can be used to filter or collect debris and soluble pollutants, including gutter leaf-guards, rain heads, screens, and/or first-flush devices. First-flush devices are important when rainwater is collected without the use of gutter leaf-guards, leafslides, or rain heads, or if the rainwater is to be used for human consumption.

The simplest roof-washing system is a first-flush device that consists of a standpipe (the diversion chamber for collecting the initial rainwater runoff) and a gutter downspout located prior to the cistern or storage tank inlet. When the first rainfall enters the standpipe, the pipe fills, and a floating ball seals the entrance to the diversion chamber, sending rainwater to the cistern. Because a typical standpipe does not automatically outlet to a storm drain, a screw-on cleanout plug should be located at the end of the standpipe. If it is not the self-draining variety, the standpipe should be emptied after each rain event. This will eliminate standing water from becoming foul from debris and soluble pollutants, and thereby contaminating future collected rainwater.

Another diversion device is a roof washer, which consists of a 30- to 50-gallon box, with leaf strainers and a filter, placed just ahead of the storage tank. Several models of roof washer are commercially available. Regardless of which type you use, cleaning the washer is imperative. Otherwise, clogging can result, restricting the flow of rainwater, and the stagnant water can encourage pathogen growth.

Storage

Cisterns or storage tanks represent the largest investment in a rainwater harvesting system, since already-existing buildings have most of the other components: a roof, gutters, and downspouts.

Above-ground tanks are available at most farm-supply and building centers. They allow for easy inspection and water extraction/draining by gravity. However, they also

A storage tank with a SafeRain first-flush diversion valve, which operates on flow rate instead of initial quantity.

Courtesy www.saferain.com.au

Courtesy www.corgaltanks.com

This 8,800-gallon, galvanized storage tank requires a lining to make it suitable for potable water.

take up yard space, can be expensive, and are susceptible to damage from constant exposure to the elements. Below-grade storage systems generally are reasonably priced, although you'll have to budget for excavation expenses. They require little or no above-ground space, and permit thinner cistern walls due to the support of the surrounding ground. However, extracting water from below-grade systems is more difficult—requiring a pump unless a tank is buried on a hill above its end use—and leaks and failures are more difficult to detect. In addition, tree roots or overhead traffic may damage a below-grade storage system.

Whether you go with above- or below-ground, a cistern that is kept cool and devoid of sunlight allows water quality to increase with time. When photosynthesis cannot take place, most organisms die as their food source is eliminated. With each rain event, a new supply of sediment and organisms will enter the storage unit. The sediment, while not usually unhealthy, can initially discolor and flavor the water, but will ultimately settle to the bottom of the storage container. It is best to remove water from a cistern or tank at a position that is farthest from a runoff inlet to allow settling before the water is used. Some storage containers may require baffles, inflow smoothing filters, or turbulence dissipaters to slow remixing with the aged water.

Rainwater Harvesting Costs

Collection	Estimated Cost	Typical Capacity /Size
Gutters	$0.30–$12.00 /lineal ft.	—
Roof Washing		
Vertical or horizontal box roof washers	$460–$1,000	—
Storage		
Precast concrete or ferro-cement tanks	$0.35–$1.50/gal.	Any
Fiberglass	$0.50–$2.00/gal.	500–20,000 gal.
Steel, corrugated & galvanized with liner	$0.30–$2.79/gal.	150–104,000 gal.
Polyethylene	$0.50–$1.90/gal.	210–5,000 gal.
Polypropylene	$0.35–$1.00/gal.	290–20,000 gal.
Welded stainless steel	$0.80–$4.00/gal.	Any
Wood (treated, with liner)	$0.88–$2.06/gal.	Any
Stone	Up to $1.00/sq. ft.	Any
Invisible structures underground retention reservoir	$8.00/cu. ft.	Any
Atlantis underground storage tank	$4.84–$5.15/cu. ft.	Any
Conveyance		
Prefilters	$50–$80	—
Pressure tanks	$200–$1,000	—
Pumps	$500–$600	0.75–1.00 hp
Filtration		
Cartridge filter sets	$100	—
1-micron filter	$265	—
Reverse-osmosis filters	$400–$1,500	—
UV filters	$300–$1,000	—
Ozone disinfection system	$700–$2,600	—
Chlorine disinfection systems (automatic dosing)	$600–$1,000	—
Chlorine disinfection system (manual dosing)	$1.00/dose	—

Courtesy Heather Kinkade

A variety of pumps are acceptable for rainwater distribution. This submersible pump has a floating intake to avoid sediment on the bottom of the tank.

Distribution

Stored rainwater may be conveyed (or distributed) by gravity or by pumping. If a tank is located uphill or above the point of use, gravity may work. Most plumbing fixtures, appliances, and drip irrigation systems require at

least 20 pounds per square inch (psi) for proper operation. (Standard municipal water pressures are typically in the 40 psi to 80 psi range.) As a general rule, water gains 1 psi of pressure for every 2.31 feet of rise, which would mean positioning a storage cistern almost 100 feet above the house to achieve typical household pressure.

In most installations, placing a tank above its point of use will also place it above the source, which is often the roof of the building where the end use is. Because of this, pumps, rather than elevated tanks, are typically used to extract both below-grade and above-grade stored water. Submersible or at-grade pumps may be used in any rainwater storage system. Self-priming pumps with floating screened intakes and automatic shutoffs—for times when water levels are insufficient—are recommended.

Generally, well pumps or any type of submersible pumps, as well as a pump located outside the tank, can be used to transfer the rainwater out of a tank. Some pumps keep the line pressurized, eliminating the need for a pressure tank. When the rainwater is brought into a house, a pressure tank is typically used in combination with a pump. Using a pressure tank saves wear and tear on the pump by reducing its run-time.

Purification

Rainwater intended for human consumption (potable) should be screened, settled, filtered, and disinfected. When stored water is being used, sediment filtration should be a maximum of 5 microns, followed by a 0.5-micron carbon filter or an equivalent 1-micron absolute filter. These ultrafilters should be NSF approved for cyst removal, since you'll want them to remove disease-causing giardia and cryptosporidia.

Solar Purification

Solar water distillation systems are among the simplest water purification systems available. No filters or membranes are required, no moving parts are used, and no electricity is needed.

Solar stills have a shallow pan with a sloping glass cover. Water is directed to the pan where it is heated by the sun. The water evaporates from the pan, rises, condenses on the underside of the glass cover, and runs down its slope into a collection trough and into a clean container for storage. The contaminants left behind in the pan should be flushed regularly. Solar stills can be mounted on roofs or on ground structures.

Courtesy www. solaqua.com

Specifically designed for potable rainwater filtration, the AquaEst RainPC MK II removes bacteria, and organic and inorganic contaminants.

Courtesy www. aquaesteurope.com

Most common filters are designed to be used with municipal supplies and do not have a convenient method of monitoring when they have become overloaded and are due for replacement. For safety's sake, filters connected to a cistern system should be changed more frequently than suggested by the manufacturer. Rainwater used for potable systems should be lab-tested periodically for quality.

Access

Heather Kinkade is a land-use planner, LEED accredited professional, and registered landscape architect in Arizona, and the author of the award-winning *Forgotten Rain*. She is president of Forgotten Rain LLC, a rainwater harvesting and stormwater reuse company. This article was adapted with permission from her most recent book on rainwater harvesting, *Design for Water* (New Society, 2007).

Climbing the Energy Everest

The Ups & Downs of Creating a Net Zero-Energy Home

by Mel Tyree

Living plants rely on solar energy as their primary energy source, so why not a house? In July 2000, my wife Charleen and I set our sights on building a net zero-energy home. Our goal was to demonstrate that you can operate a comfortable, modern home—even in a climate-challenged location—without burning *anything*.

The Tyrees' barn was designed to perfectly accommodate a 10 KW PV array.

At the start of the project, I was inexperienced in building design. But I had spent much of my career in biophysics immersed in numbers and calculations, working to quantify the exchange of energy and matter between sunlight, the environment, and plants. When I began running energy systems design calculations for our new home, I was amazed by how well my years of seemingly unrelated research had prepared me for the journey ahead. Along the way, we had to overcome some unique regulatory and technical challenges, but, in the end, patience and determination gave way to a carbon-neutral home that derives 100% of its energy from the sun and wind.

The motivation to build our zero-emission home came from the desire to reduce our contribution to global warming and pollution. That meant eliminating our home's dependency on all conventional fuels. Homes with solar- and wind-electric systems commonly rely on natural gas, propane, heating oil or firewood for cooking, as well as water and space heating. We wanted to prove that it is possible to live in a home that offsets 100% of its energy with renewable, nonpolluting sources.

The first step was to find a location for our new home. Over several months, we came across four suitable properties in our home state of Vermont, but our potential neighbors were opposed to the notion of having a wind turbine in *their* backyard. Eventually we widened our search to the North Country of New York, where we found a beautiful, affordable property that met our needs—102 acres of forest and pasture, in Ellenburg, just north of Adirondack Park at 44.9° north latitude.

New York state's net-metering law for residential RE systems allowed excess energy credits to be carried forward to the end of the annual billing cycle and supported property tax exemptions for the systems' value. In addition, the New York State Energy Research and Development Authority

Erecting the tower—10 feet at a time.

Final section—120 feet up.

Hoisting the rotor.

(NYSERDA) offered generous financial incentives for both PV and wind systems. Based on some initial conversations, neighborhood support for wind generators seemed positive. I also learned that the town of Ellenburg has no zoning regulations that prevent erecting a 120-foot tower for the wind genny. Our project's future looked bright. We closed on the property in October 2003 and were on our way.

Our Big Picture Energy Plan

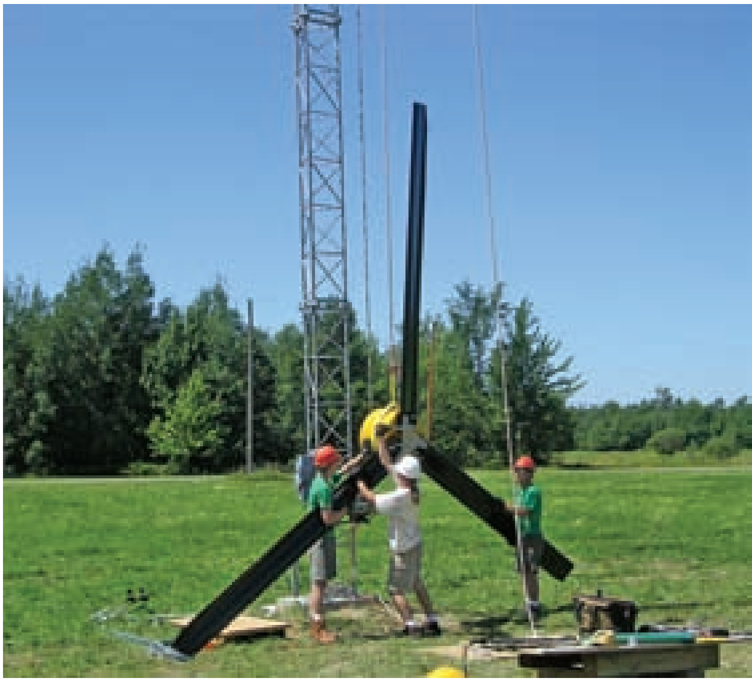
Offsetting 100% of our energy needs would be no small feat given the cold, cloudy winters and humid summers in Ellenburg, which sits about six miles from the Canadian border. Key to our plan was a ground-source electric heat pump for space heating and cooling (see "Get Pumped" sidebar). Producing the electricity needed to run our heat pump—an estimated 7,400 kilowatt-hours per year—would require substantial RE generation capacity. And while our heat pump is also designed to assist in domestic water heating, we'd still need to generate about 3,000 KWH annually for our tank-style, backup electric water heater. Even though using energy-efficient appliances and lighting would help keep the remainder of our loads to a minimum, our annual electrical load still came close to 17,000 KWH.

Because net-metering eligibility in New York limits the size of residential PV systems to 10 KW, we planned to add a 10 KW wind turbine to the 10 KW PV array. Based on our site's solar and wind resources, this hybrid system was projected to offset 100% of our home's energy use. Ice storms can cause extended power failures in our area, so we wanted a grid-tied PV system with battery backup, which would supply electricity for the critical loads: an emergency backup oil furnace, well pump, refrigerator, some lights, and a microwave.

Working the System

Our plan was to install wind and PV systems prior to building the house, and we didn't want to waste any time. Within days of closing on the property, we contracted Sustainable Energy Developments Inc. (SED) of Ontario, New York, to install a 10 KW Bergey wind generator on a 120-foot tower. But, in all the excitement, we overlooked a few critical details. Apparently, our local power company, New York State

Even just the rotor assembly of the 10 KW Bergey is big and heavy.



Electric & Gas Corp. (NYSEG), was not very supportive of on-site residential power generation. Even more sobering, at that time, was that New York's residential net-metering legislation for wind systems was not as favorable as it was for PV systems. We would be credited only 4.2 cents per KWH for excess energy our wind turbine produced but would have to pay 17 cents per KWH for this "premium" electricity when we needed to buy it back from the utility.

Another hurdle came when we discovered that the state's property tax exemption for solar- and wind-electric systems was voluntary, and that our local tax authority was one of the few in the state that had opted out of the program. Based on the full-retail value of our planned RE systems, the associated property tax payment would amount to $3,000 per year. By the numbers, our project made little economic sense. But we weren't going to give up that easily.

We became frequent faces at city council and school board meetings, grabbing anyone and everyone's ear whenever we could to make our case for reversing the property tax policy. For all our effort, we did persuade the local tax assessor to add a new stipulation that the property taxes for each new system would not exceed $227 per year—versus the $3,000 we had originally projected. Other good news was that the New York state legislature was on board to approve a bill that restructured the net-metering rules for wind energy. According to these rules, which went into effect in 2006, we would get full retail value for excess energy produced in any given year, provided that the energy credits were used within the same 12-month period. With the dollars-and-cents side of things looking more promising, we decided to proceed with our project.

Wrangling the Wind

Due to all of the regulatory hurdles, it wasn't until August 2005 that the Bergey wind generator was up and spinning. The actual wind turbine installation went very smoothly. SED did a fantastic job assembling the tower, turbine, and balance of system components. However, we couldn't find an appropriately sized crane within any reasonable distance from the site to lift a pre-assembled tower. The resulting section-by-section installation of the tower using rigging and a gin pole turned out to be one of the highlights of the project for me.

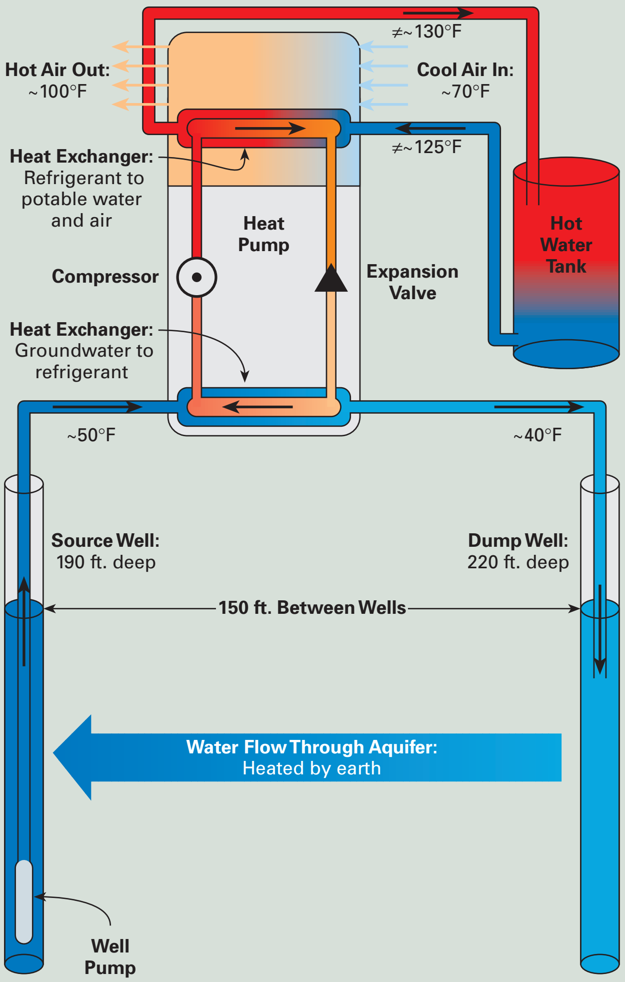
Anyone with long-term experience with home-scale wind systems will tell you that the technology isn't for the faint-hearted, and my experience mirrors this seasoned perspective. Compared to low-maintenance PV modules, which have no moving parts and typically carry 25-year warranties, wind turbines are inherently reliant on rotating parts that are exposed to some of the harshest conditions imaginable. Turbines have a tough job to do and, over time, can fail. While our wind turbine installation went without a hitch, some technical issues with the system still lay ahead.

Not all wind turbines, inverters, and their use together in a given system will produce similar results when it comes to producing energy. In our system, on days where wind speeds

Get Pumped

The ground-source heat pump that heats and cools our home—and supplements domestic water heating—is our biggest load, consuming almost half of the electricity our RE systems generate. This amount might sound high, but it's actually quite low because of the high efficiency of the heat pump and its ability to take advantage of ground temperature. If we burned carbon-fuel (like oil or natural gas), the heating load would account for 72% of our home's total energy consumption.

Since our goal was to reduce our carbon footprint to zero, fossil-fueled appliances were out. Electric resistance heating would have been an option, but ground-source heat pumps deliver heat with less energy input. A ground-source heat pump takes advantage of the relatively constant temperature below frost level in the ground—transferring ground heat to the home in the winter and the home's heat to the ground in the summer. These systems put out a lot more heat energy than the amount of electric they consume (300% plus), even on the coldest of winter nights. In our system, for every 4.3 KWH of energy sent to the house, the compressor consumes just 1 KWH for an overall efficiency of 330%. (For more on heat pumps, see "Heat from the Earth—A Heat Pump Primer" in *HP98*.)



tech specs

Overview

System type: Grid-tied, solar- and wind-electric with battery backup

Location: Ellenburg, New York

Solar resource: 4.3 average daily peak sun-hours

Average annual PV system production: 10,400 AC KWH

Wind resource: 12 to 13 mph average wind speed

Average annual wind system production: 8,800 AC KWH

Utility electricity offset: 100% plus

PV System

Modules: 80, BP 3125, 125 W STC, 17.6 Vmp

Array: Five subarrays of 16 modules each, four modules per series string, 70.4 Vmp, 10 KW STC total

Array installation: UniRac SolarMount racks on south-facing roof, 45° tilt

Array combiner box: Five OutBack PSPV with four 15 A breakers each

Batteries: 36 Rolls Surrette KS-21, 2 VDC nominal, 1,000 AH at 20-hour rate, flooded lead-acid

Battery bank: Three series strings, 3,000 AH total at 24 VDC nominal

Charge controllers: Five OutBack MX60, 60 A, MPPT, 70.4 Vmp input, 24 VDC nominal output

Inverters: Two Xantrex Series 2 SW4024 inverters with Grid Tie Interfaces (GTIs), 4 KW each, 8 KW total, 24 VDC nominal input, 120/240 VAC output

System performance metering: Two form 12S AC KWH meters

Wind System

Turbine: Bergey Excel-S

Rotor diameter: 23 ft.

Rated energy output: 10,800 DC KWH/month at 12 mph (5.4 m/s)

Tower: Bergey XLG37 guyed-lattice, 120 feet

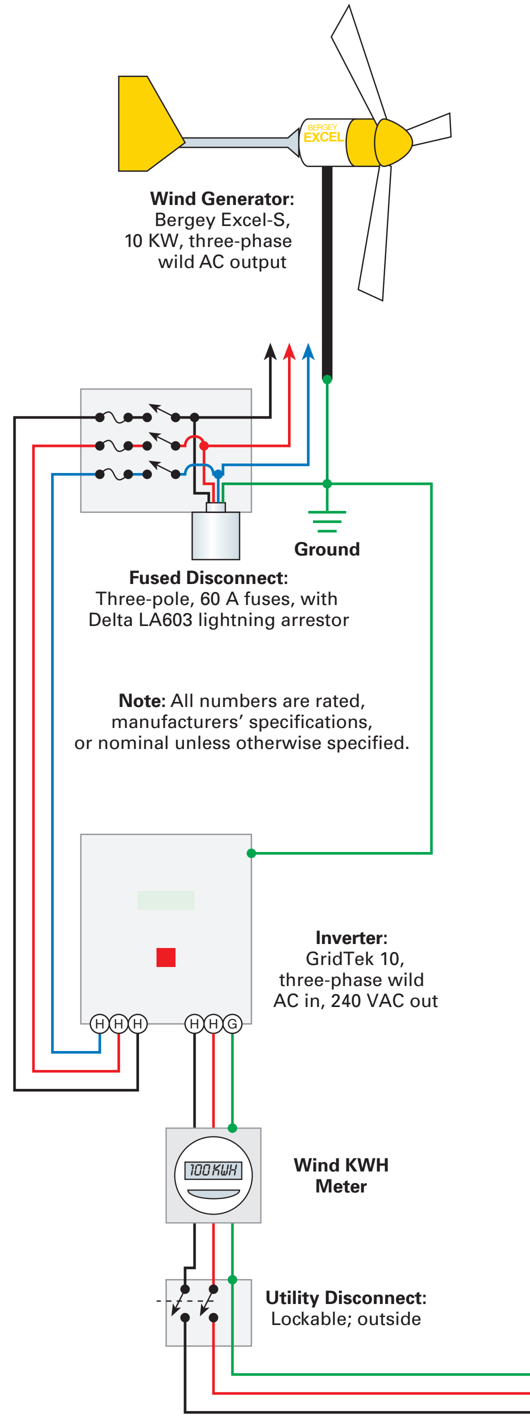
Inverter: Xantrex GridTek 10, 10 KW, batteryless grid-tie, 240 VAC output

System performance metering: AC KWH meter

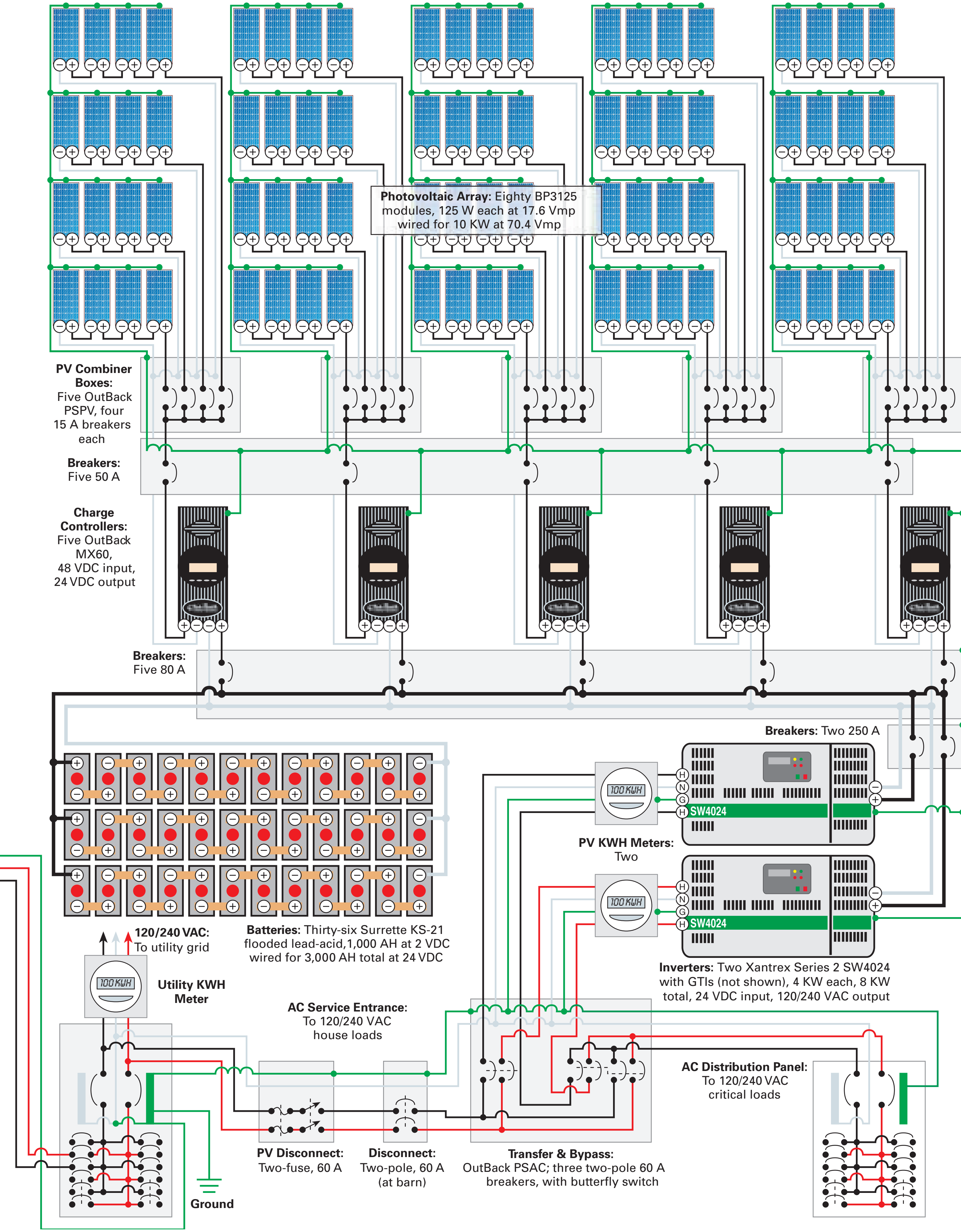
repeatedly exceed 28 mph, our Xantrex GridTek 10 inverter spends much of its time in standby mode. The turbine's power output increases as blade speed increases to 300 rpm—where the nominal maximum output of 10 KW is produced. In winds exceeding 28 mph, the turbine's rpm continues to slowly increase. At 420 rpm (12.4 KW output), the inverter goes into standby mode to protect it from being overloaded. The inverter is designed to stay in standby for five minutes before turning on again. It will attempt to go back online regardless of how fast the blades are spinning.

But if the inverter tries to reconnect when the turbine is spinning faster than 460 rpm, it goes offline and stays that way until I notice it and do a manual reset. At times, there may be hours or days of lost production if I'm traveling or don't notice that the inverter is offline. This issue isn't unique to my unit: Testing at the National Renewable Energy Laboratory (NREL) documented this behavior back in 2002. Because I only recently added anemometers to the tower for measuring wind speed, I can't yet be certain how much energy production is lost due to this issue, but I estimate between 8% and 15%.

Considering what was to follow, the inverter performance issue was minor. In February 2006, the wind generator threw a blade. This caused the turbine to vibrate so violently that it broke the pivot point connecting the turbine mount to the tower and the turbine fell—my $23,000 wind generator was toast. Fortunately, the 1,100-pound turbine did not hit any guy wires on its way down—otherwise it could have taken down the tower with



Mel and Charleen with the PV system's component wall.



Photovoltaic Array: Eighty BP3125 modules, 125 W each at 17.6 Vmp wired for 10 KW at 70.4 Vmp
PV Combiner Boxes: Five OutBack PSPV, four 15 A breakers each
Breakers: Five 50 A
Charge Controllers: Five OutBack MX60, 48 VDC input, 24 VDC output
Breakers: Five 80 A
Breakers: Two 250 A
100 KWH
H
N
G
H
SW4024
PV KWH Meters: Two
Batteries: Thirty-six Surrette KS-21 flooded lead-acid,1,000 AH at 2 VDC wired for 3,000 AH total at 24 VDC
120/240 VAC: To utility grid
Utility KWH Meter
AC Service Entrance: To 120/240 VAC house loads
Inverters: Two Xantrex Series 2 SW4024 with GTIs (not shown), 4 KW each, 8 KW total, 24 VDC input, 120/240 VAC output
AC Distribution Panel: To 120/240 VAC critical loads
PV Disconnect: Two-fuse, 60 A
Disconnect: Two-pole, 60 A (at barn)
Transfer & Bypass: OutBack PSAC; three two-pole 60 A breakers, with butterfly switch
Ground

Ready to be wired: A bank of 36, 2-volt cells can provide about 60 KWH hours of backup electricity.

it. A batch of defective blades was the cause of the failure. The system sat idle for almost six months until we received a new turbine in August 2006. The five-year warranty covered all the costs, and Bergey generously compensated us for the value of our lost electrical production—above and beyond the warranty terms.

Harnessing the Sun

In the spring of 2005, while we waited for our replacement wind turbine to arrive, construction of a new barn was underway. The barn faces toward true south with 1,000 square feet of roof area for our 10 KW PV array. We contracted Vermont Solar Engineering to design and install a grid-tied solar-electric system with about 60 KWH (at 80% depth of discharge) of battery backup for critical loads. An array of 80 BP Solar 125-watt modules would feed five OutBack MX60 charge controllers. But before we got very far into the project, we hit a few more regulatory stumbling blocks.

NYSEG rules did not allow both a wind and a PV net-metered system on the same residential line. A call to NYSERDA confirmed this, but they said they were in the process of redrafting rules. NYSERDA contacted all power companies in New York and found that Niagara Mohawk would allow that combination. This gave the NYSERDA the leverage they needed to rule that *all* New York power companies must follow the policy allowed by Niagara Mohawk.

That good news came with caveats, though. Due to the state's 10 KW cap on residential net-metered PV systems, NYSEG would not approve the use of more than 10 KW of rated inverter capacity. This restricted our inverter choices and ultimately resulted in a less-than-optimal system. To meet code, we ended up undersizing the inverter capacity to 8 KW and selecting older-model Xantrex SW inverters. It was a clear case of poor regulations dragging technology down with them, as a variety of more efficient battery-based inverters are currently on the market.

Setting aside the regulatory walls we hit, our PV system has been operating without a serious glitch since November 2006. We were pleased with the job Vermont Solar did on our installation, and they promptly corrected a couple of minor problems.

Hitting Zero

At long last, the day came to break ground for our new home. After nearly four years working through the regulatory and technical issues related to the power systems, building the house went surprisingly smooth, taking only about four months. By January 2008, we were moved into our new two-story home. The home features all the modern conveniences and amenities, as well as low-E windows, low-toxicity materials, and energy-efficient electric appliances.

Although the up-front costs of our home's energy systems tacked on an extra 40% to the cost, the investment was well worth it. NYSERDA provided a 50% rebate on the installed cost of both systems, and we were able to take advantage of state and federal tax credits, which lowered our initial system costs significantly. In the long run, as utility rates continue to climb, the cost to operate the home will be far less than a conventional home that depends on fossil fuels. Over the past nine years, the price of electrical energy has been increasing at 3.7% annually and fuel oil has increased 14.6% per year. Taking this into account, I've calculated that our initial return on investment is about 5.4% per year and increases each year as the projected cost of energy goes up. This results in an estimated financial payback period of 10 to 11 years.

While there were definitely some frustrating phases during the project, our solar-electric and wind systems have been operating smoothly for more than a year. I'm proud to say that we've reached an actual production of 19,000 KWH, and are offsetting more than 100% of the energy required to heat, cool, and power our new home, without relying on *any* fossil fuels or wood. Despite the problems, I wouldn't hesitate to tackle the project again.

Access

Mel Tyree (Mel.Tyree@ales.ualberta.ca) is a university professor who likes to build scientific equipment and tinker with electronics. As a public service, he compiles and posts information about small wind turbines on a University of Alberta Web page, called the Small Wind Information Exchange Program (www.ualberta.ca/~mtyree/SWIEP).

Sustainable Energy Developments Inc. • 585-265-2384 • www.sed-net.com • Wind power equipment and installation

Vermont Solar LLC • 800-286-1252 • www.vermontsolar.com • Solar-electric equipment and installation

Small Wind Info:

AWEA Small Wind Listserve • www.groups.yahoo.com/group/awea-smallwind/

SWIEP • www.ualberta.ca/~mtyree/SWIEP or http://tech.groups.yahoo.com/group/SWIEP • Consumer reporting group on wind systems

System Components:

Bergey • www.bergey.com • Wind turbine

BP Solar • www.bpsolar.com • PV modules

OutBack Power Systems • www.outbackpower.com • Charge controllers

Surrette • www.surrette.com • Batteries

UniRac • www.unirac.com • PV mounts

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Pipeline

Hydro-Electric Penstock Design

by Jerry Ostermeier

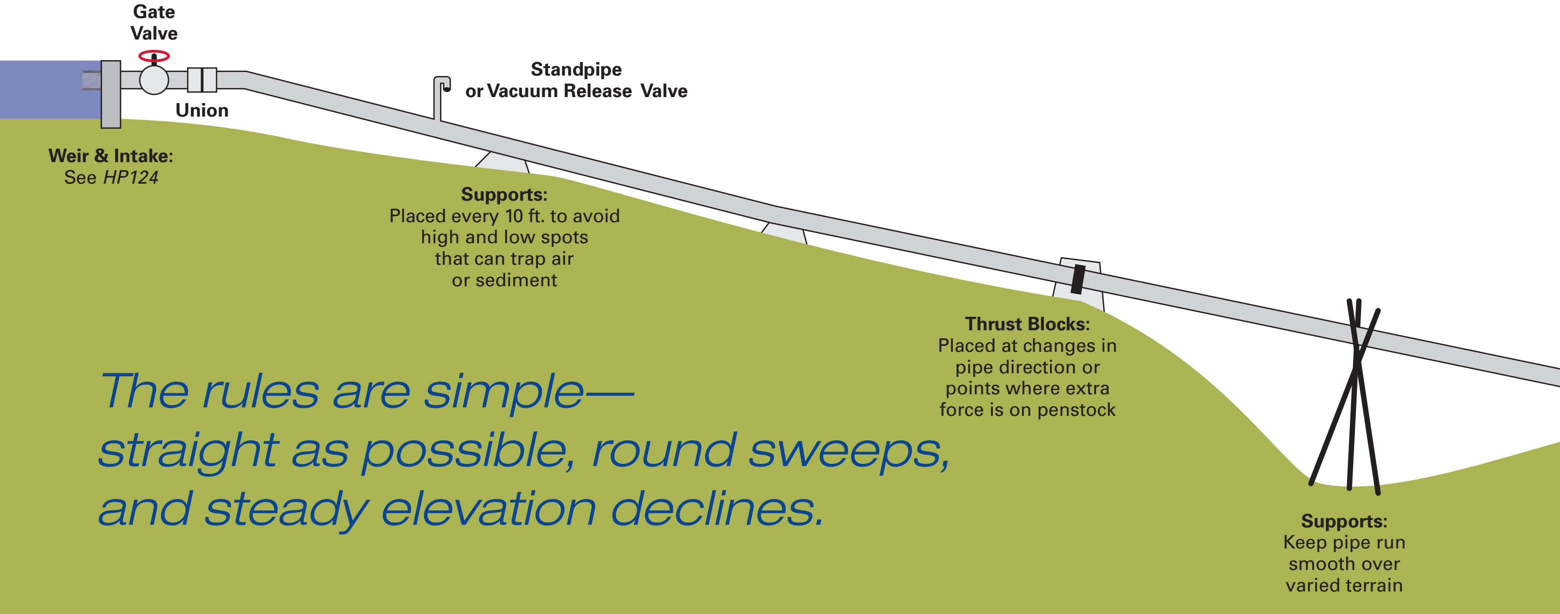
Intake and top section of penstock with standpipe vent.

If you want to extract every last bit of energy from your microhydro system, three main components are critical to optimal performance—intakes, penstocks, and turbine selection. Intake options were covered in *HP124*, along with various methods of diverting water from the source. Here, we'll talk about best practices for penstocks, which channel the water from the intake to the microhydro turbine, building up pressure along the way.

In many ways, the penstock (pipeline) is the most important part of your hydro-electric installation. It's the "engine" in your system. Trying to cut corners on this design element can cost you in performance. And poorly installed penstocks can give you trouble, instead of what you're really after—maximum *energy* generation.

Pipe Types & Pressure Ratings

Almost any type of pipe will work as a penstock, at least to some degree. The most common types are white polyvinyl chloride (PVC) and "poly pipe" (black polyethylene, PE; or high-density polyethylene, HDPE), which come in several pressure ratings. Common drainpipe is thin-walled and not rated for pressure. Though it can accommodate up to about 30 feet of head if you are careful opening and closing valves, drainpipe is not normally a recommended choice.



The rules are simple—straight as possible, round sweeps, and steady elevation declines.

In selecting pipe with the correct pressure rating, be sure to allow an extra 40% above the static water pressure in the pipe. For example, with 200 feet of head, the static pressure is about 87 pounds per square inch (psi). Multiply that by 1.4 (140%) to reach the needed pipe pressure rating of 122 psi. To compute the static pressure for the proposed penstock (in psi), divide the total head (in feet) by 2.3.

To save on penstock costs, a system can use pipes of increasingly higher pressure ratings as it gets closer to the bottom of the run, where pressure is highest. In that case, calculate the pipe pressure ratings for different total heads as you move down the pipeline.

Some hydro installers will disagree, but my strong preference for penstocks is to use PVC pipe in 20-foot lengths with a bell end for gluing lengths together. Splices used for other pipe types are not reliable at high pressure or for unrestrained pipe movement. Thin-wall poly pipe comes in a long roll and can be easy to use, especially if your penstock has to weave through trees and over rocks to the turbine, and if you can complete the entire run without splices. Thick-wall poly pipe requires special butt-welding equipment. The welds will leave a bead on the inside of the pipe that will affect flow. In our area, the critters tend to like chewing on poly pipe, but in other parts of the country, they seem to have a taste for the white PVC.

Aluminum pipe can be easy to get in agricultural areas but generally should only be used for pressures up to about 125 psi. It should not be buried unless treated to deal with the acidity in soils. Steel will handle very high pressure but should also not be buried, since it will rust out over time. Common PE poly pipe and HDPE have pressure ratings around 80 psi. They are available at even higher pressure ratings but can be hard to get in larger sizes.

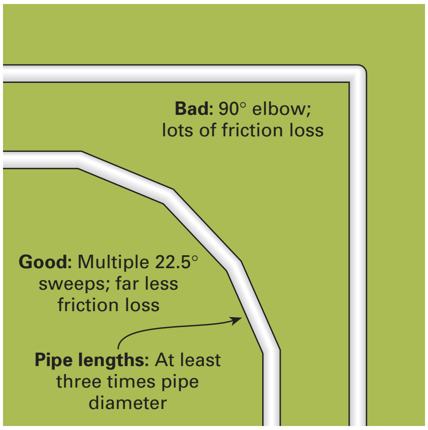
Dealing with Losses

Aluminum, steel, and poly pipe have comparatively high friction loss (resistance to flow), so it is important to factor this loss into sizing—which can play a part in system cost. As with different types of electrical wire, every pipe type has different resistance to flow based on the roughness of the walls. Also like wire, the diameter of the pipe determines the resistance to flow and how much flow the penstock can handle. In very high-head situations, steel pipe might be the only pipe capable of handling the high pressures.

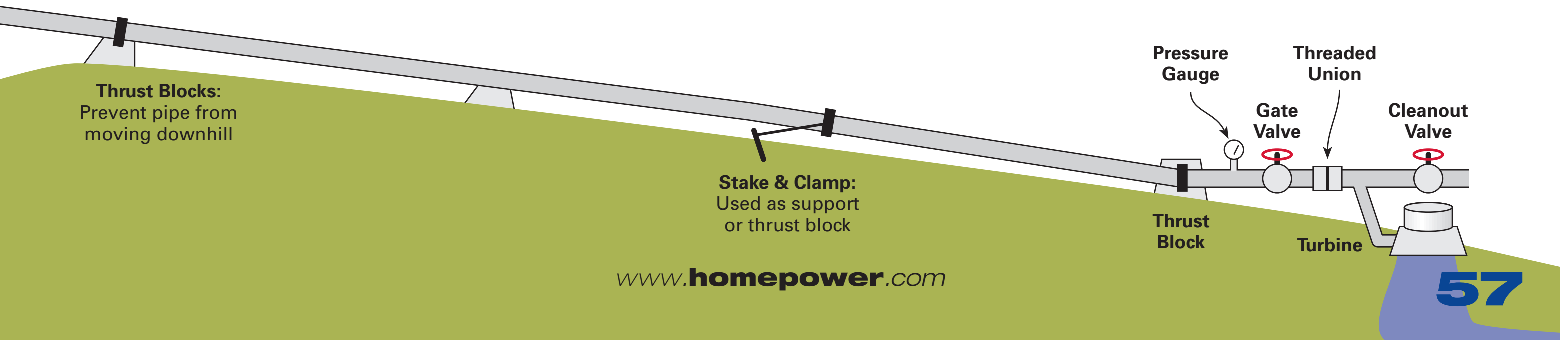
Pipe friction-loss tables for each pipe material will tell you how much flow a particular pipe size can handle. Then, by comparing prices, you can determine if changing pipe diameter or material type is worthwhile. Steel and aluminum pipes generally have double or more the resistance of PVC, and the larger sizes tend to make it prohibitively expensive for use in small systems.

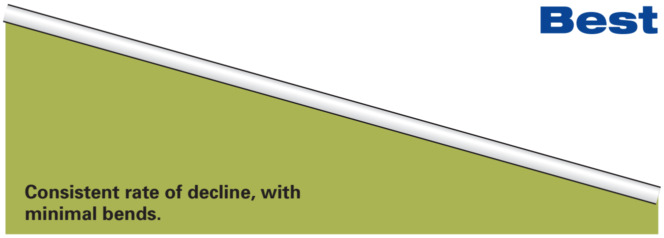
Friction-loss tables are commonly used for hydro penstock sizing (visit www.homepower.com/penstocktables), but precise friction-loss calculations can become complicated because they deal with velocity, pressure rise, critical time, and pressure wave velocity—frankly, it can become a physics exercise. But more simplified pipe sizing "rules" can address all the factors adequately. The following rules are for typical PVC schedule-40 pipe with runs of 300 to 1,200 feet. Short,

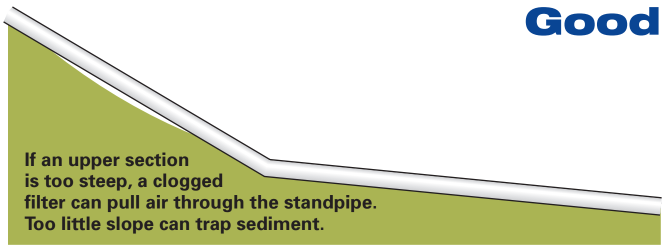
Round the Bend

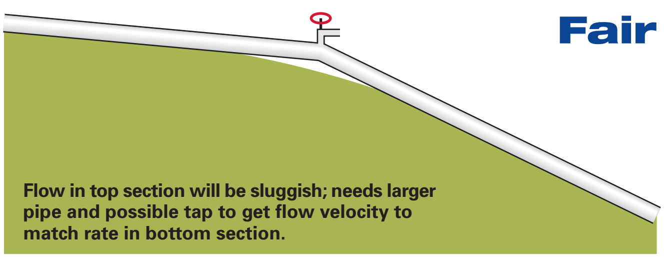


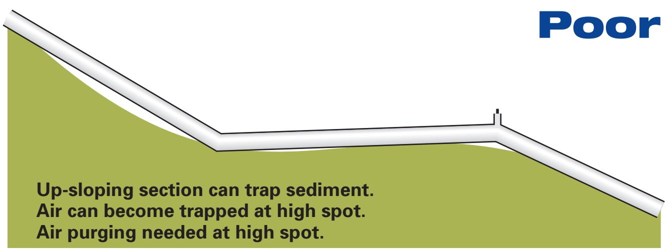
Choose your pipe type based on head, flow, run length, and your budget.











straight pipe runs can exceed these max flow rates a little—longer pipe runs need to be reduced.

- Up to 7 gpm can use 1-in. pipe (300 ft. of static head or higher)
- Up to 15 gpm can use 1.25-in. pipe (250 ft. of static head or higher)
- Up to 25 gpm can use 1.5-in. pipe (200 ft. of static head or higher)
- Up to 45 gpm can use 2-in. pipe (any head)
- Up to 75 gpm can use 2.5-in. pipe (any head)
- Up to 110 gpm can use 3-in. pipe (any head)
- Up to 190 gpm can use 4-in. pipe (any head)
- Up to 300 gpm can use 5-in. pipe (any head)
- Up to 430 gpm can use 6-in. pipe (any head)

The "rules" list is based on rounded estimates. If you are pushing the envelope within a pipe size, it is usually better to go bigger. This strategy will almost always improve system performance. The same holds true for long pipe runs. Bigger pipe will make more power available to your hydro plant at the bottom end of the penstock.

Web Link: For more information on determining pipe and fitting friction loss, go to www.homepower.com/penstocktables

Penstock Protection

Poly pipe is well known for being chewed on by rats, raccoons, and bear, to name just a few—but PVC has been attacked too. On the other hand, poly pipe can sometimes be better than harder-shelled pipe types because it is relatively freeze-tolerant and can be a little tougher for laying over treacherous terrain. Buried pipe offers more protection from toothsome critters, freezing, and falling trees, and more stability to handle pipeline movement.

If you are burying the penstock, the recommended trench depth is 2 feet for pipe up to 4 inches in diameter. Bury larger pipe at least 2.5 to 3 feet deep. Also be sure to check average frost depth in your area. Although moving water generally won't freeze in most climates, snafus—such as blocked nozzles in the turbine—can stop the flow of water and lead to freezing during a cold snap.

The trench bed should be free of sharp rocks that can damage the pipe. A layer of sand or pea gravel under the pipe works great. The trench should not curve beyond the

Supporting the penstock with brackets and cables helps keep the run smooth and prevents pipe movement.

Valves & Vents: Microhydro Relief

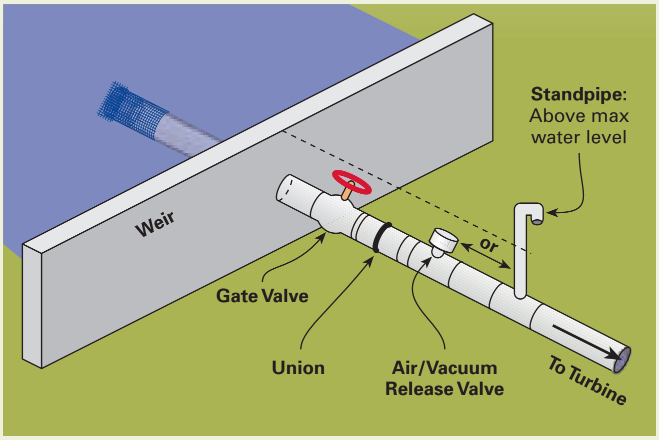
Placing a valve between the intake's pipe and the main penstock can be quite handy when you need to shut down a hydro system for maintenance or freezing weather. Any type of valve, other than a plastic slide-gate, will work. I usually place a union close-coupled just below the gate valve, so I can clear pebbles or other debris that might accumulate in the cavity at the bottom of the valve and prevent the valve from closing completely.

Sometimes, instead of adding a valve, the connector between the penstock and the intake pipe, such as a rubber compression union, can be removed to keep water out of a penstock. This is not only a hassle and slower than a valve but also problematic if the pipeline has to be shut down in a hurry. Some systems may use a rubber hose to connect the two pipes. In this case, it is important to make sure that the hose is suction-rated and has wire coil molded into the rubber to prevent collapse. A screw-apart union or a compression splice can also work to keep water out of the penstock.

At the turbine, consider using a gate valve for the main shutoff—especially for high-head systems. Compared to a ball valve, they operate slower, reducing the risk of water hammer—an effect caused by stopping a flow of water too quickly. There's a lot of kinetic energy in water flowing down a pipe, and gradually slowing the flow to a stop will avoid the high pressures that can break or weaken a pipe and its joints. A ball or vane valve can be a better choice on lower-head applications because they create less turbulence at their typically higher-flow rates. Regardless of your system type, this rule is paramount: Be careful to shut the main valve at the turbine slowly to avoid water hammer.

Venting also should be included in any design, especially in a system that has an upper shutoff valve, because there is a chance that the intake screen could become blocked enough to collapse the penstock. The down-pipe movement of water can create tremendous suction in the pipe if its flow is stopped from above. At 200 feet of head, a pipe has greater risk of collapsing from suction than breaking from water hammer when a turbine shutoff valve is suddenly closed.

A manual valve works as an air–vacuum release.



Top-of-penstock components.

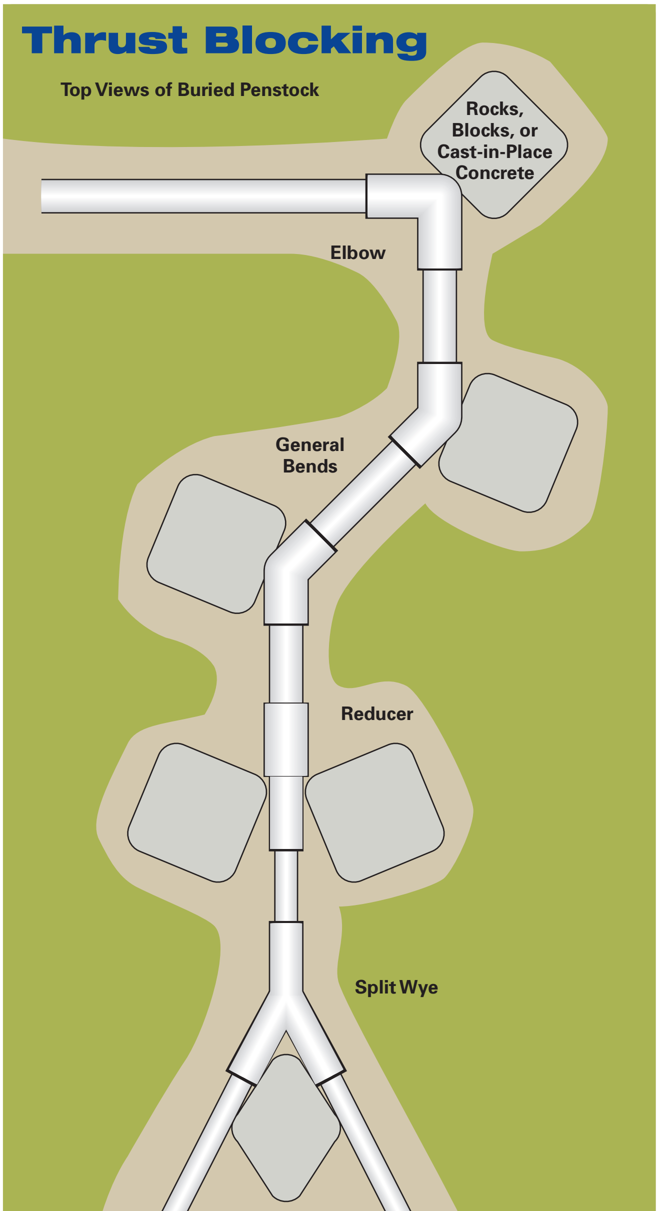
The diagram above shows an automatic air-vacuum-operated release valve. If a vacuum occurs, the valve lets the penstock drain without damage. Penstocks 4 inches and smaller should use a 1/2-inch or larger valve. Larger pipe should have a valve sized no less than one-sixteenth the diameter of the penstock.

Another method for suction relief uses a standpipe, which must be placed below the valve to the penstock and extend above the maximum level of the water source at the diversion. This keeps the penstock open to the atmosphere above the water level. Be sure to place the standpipe far enough down the penstock so that the system will have enough suction to draw through the intake instead of sucking air down the standpipe.

A standpipe can also help purge from the penstock any air bubbles mixed in with the water that result from turbulence in the intake area. Spring-loaded and manual vents are also available. Avoid the floating ball type because they tend to open when they shouldn't, sucking air at higher-flow rates or in the event of partially obstructed intake filters. Air trapped at any high points in the pipeline can slow or stop water, decreasing or even stopping turbine output. At low heads (32 feet or less), this is not usually a problem, but air in the penstock can also lead to premature bearing failure in the turbine, or even damage the runner, when an on–off repeated pulse set up by water–airspace repetitions acts like little hammer blows hitting the runner. The higher the head and the bigger the airspace, the greater the blow to the turbine.

Another air-removal method is to use permanently installed manual valves to bleed the air from the high spots when the penstock is full but not flowing. Some hydro system owners will simply thread a screw into the penstock at the high points, and occasionally back the screw out to bleed any accumulated air.

The bottom of the system should always include a drain valve for draining all piping or bypassing the hydro plant. In cold climates, the unburied end of the penstock, valves, and hydro manifold are susceptible to freeze damage if the flow is stopped, so it is critical to keep the drains or bypass open if freezing weather is imminent. This applies to all nozzles on the hydro—not just the ones that are currently "on." Re-jet the nozzles if necessary to be able to open them all. If you can't, it is better to shut the whole thing down and drain everything. Not paying attention to this can cost you several hundred dollars in freeze damage.



recommendations for the particular pipe being laid in it, or else the pipe could break or distort to the point of flow restriction.

Water weight and normal vibrations from water moving through the pipe can cause the pipes to move. Where a change in flow direction occurs, like at an elbow, powerful forces can break or separate connections. "Thrust blocking" at the bends in the system prevents that pipe movement. Blocking is usually unnecessary for 3-inch or smaller pipe that is buried in most soils. The illustration above shows recommended thrust blocks for different bends commonly found in penstocks. For pipes up to 5 inches, it is prudent to dig a little deeper at the critical points, build a makeshift form, and pour concrete over the entire corner. Though the concrete does a good job at keeping the pipe in place, it also can make pipe replacement or repairs difficult later on. For larger pipe and high-flow situations, the size of the thrust block must be calculated precisely. (see "Calculating Thrust-Block Size" sidebar).

A penstock, heavy with water, should be anchored at the turbine to keep from moving downhill. How much anchoring is necessary is calculated in the same manner as any other thrust blocking. In areas with very steep terrain, there may be no way to apply thrust blocking in the normal manner. Instead, the pipe can be anchored with wire rope by attaching one end to the hillside's rocks or trees and the other end to the pipe, and then, using turnbuckles for adjustment.

Lower Penstock & Hydro Connection

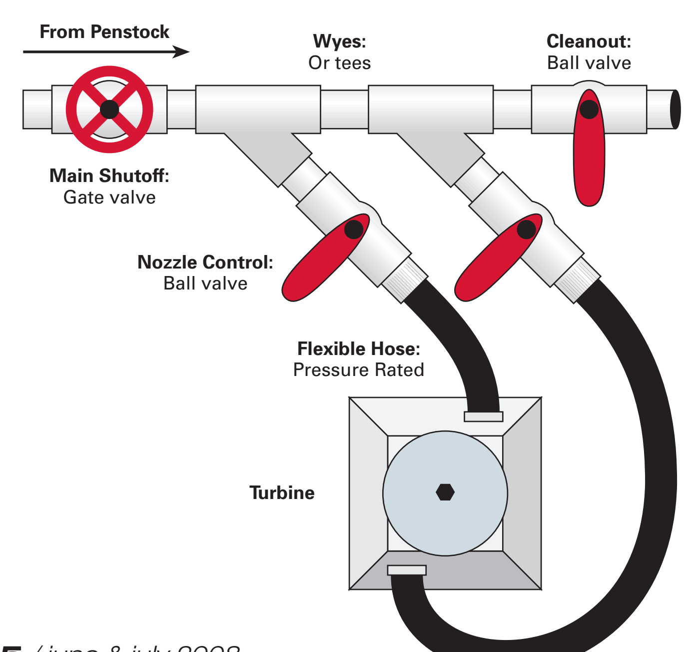
Connecting the turbine to the penstock usually involves correcting the angle of the downhill pipe run to match the turbine's angle, which is usually zero. You can change the angle with a king nipple (similar to a hose barb) and a short, high-pressure piece of rubber hose, or you can use two 22.5-degree elbows that can make any correction up to 45 degrees. Correction may be unnecessary for hydro turbines that have a gang manifold at the end of the penstock or use valves and hoses to feed the individual nozzles. Some manifolds are hard-plumbed, and will likely need an angle correction where they meet the penstock. A cleanout valve at the end of the manifold may also be helpful for draining or flushing leaves and trapped sediment.

The most visually impressive installations have the pipe exiting the ground at a 22.5-degree or 45-degree angle inside a shed or protected area that houses the hydro turbine. If you keep your turbine out of the weather, it will last longer and need less service, especially the wound-field models.

Hydro Mounting & Tail Race

Since most turbines are meant to discharge water out the bottom, it's important to design your system so the "waste" water can move away freely. In constructing a turbine mount, be sure that the cutout is not smaller than the turbine's tail-water opening. A cutout that is too small will deflect water back into the runner and reduce the system's performance.

At the Turbine



Calculating Thrust-Block Size

Preventing pipe thrust from harming a penstock is critical to a successful hydro installation. Here is a sample thrust-block design calculation for a 45-degree bend in the penstock. This case assumes that a 4-inch pipe under 87 psi of pressure is buried in medium, clay-type soil.

Determine pipeline thrust. From the "Pipe Fitting Thrust" table, the factor is 12.4 lbs./psi for a 4-inch pipe and a 45° elbow.

Calculate the total thrust at the fitting. 12.4 lbs./psi x 87 psi working pressure = 1,078.8 lbs. of thrust

Determine soil load strength. From the "Soil Load Strength" table, the soil load strength is 2,000 lbs. per sq. ft.

Calculate the size of the thrust block. 1,078.8 lbs. ÷ 2,000 lbs. per sq. ft. = 0.54 sq. ft. of thrust-block surface area

The computation means that 0.54 square feet of blocking is necessary to hold the bend against the medium clay-type soil. Concrete is usually poured over the pipe fitting, filling the area against the undisturbed trench sides for thrust blocking.

For unburied pipe or pipe in soft soils with little resistance to movement, thrust blocking needs to rely on mass instead of the area resting against trench wall. Here is an example calculation of thrust block weight for a 6-inch pipe at 139 psi with 8 degrees of deflection:

Determine the thrust factor. From the "Side Thrust" table, 6-inch pipe has 61 lbs. of thrust per 100 psi per degree of deflection.

Calculate the amount of thrust. 0.61 lbs./psi x 8° x 139 psi = 678 lbs.

This means that there needs to be 678 pounds of mass (usually poured concrete) to keep this penstock from moving at the bend.

Pipe Fitting Thrust

Pipe Size (In.)	Thrust (Lbs./psi) Tee	90° Elbow	45° Elbow	22.5° Elbow
1.5	2.94	4.16	2.25	1.15
2.0	4.56	6.45	3.50	1.80
2.5	6.65	9.40	5.10	2.60
3.0	9.80	13.90	7.50	3.80
4.0	16.20	23.00	12.40	6.30
5.0	24.70	35.00	19.00	9.70
6.0	35.00	49.00	27.00	14.00
8.0	59.00	84.00	45.00	23.00
10.0	92.00	130.00	70.00	36.00
12.0	129.00	182.00	99.00	50.00

Soil Load Strength

Soil Type	Safe Bearing Load (Lbs./Sq. Ft.)
Shale	10,000
Cemented sand & gravel; hard to pick	4,000
Good mix compact soil	3,000
Clay—medium	2,000
Clay—soft	1,000

Side Thrust

Pipe Size (In.)	Thrust Factor*
1.5	5
2.0	8
2.5	12
3.0	17
4.0	28
5.0	43
6.0	61
8.0	103
10.0	160
12.0	225

*Lbs. per 100 psi per degree deflection

A chunk of concrete, cast in place, acts as a thrust block for a small change in direction of this penstock.

Although the most common mount is a simple, 2- by 4-foot plywood, structure, built close to the water source, the most durable mounting platforms are sturdy plates on permanent concrete structures with the tail or waste water exiting the bottom or side, either into a wide opening or a drain pipe. The drainpipe needs to be at least twice the diameter of the supply pipe, with a reasonably steep downward slope. An air vent in the tailbox will help prevent the tail water from sucking on the water running through the hydro, creating a power loss on an impulse turbine. The vent also removes pressure so that water won't find its way into the front bearing, which can lead to a bearing failure in some hydro turbines.

Another popular hydro mounting method uses a modified 55-gallon metal drum, with the turbine fastened to the drum top with bolts. The bottom third of the drum is secured into the creek bank with concrete or by loading the drum with rocks. The middle third has a hole drilled out, which allows water discharge. These drums will usually last about 10 to 15 years before they rust out.

Alternatively, an up-ended culvert pipe that is 24 inches or larger can be used, though fabricating a top will be more difficult. My preferred top is a high-density polyethylene sheet at least 1/2-inch thick. This special-order item is more expensive, yet longer lasting, than plywood.

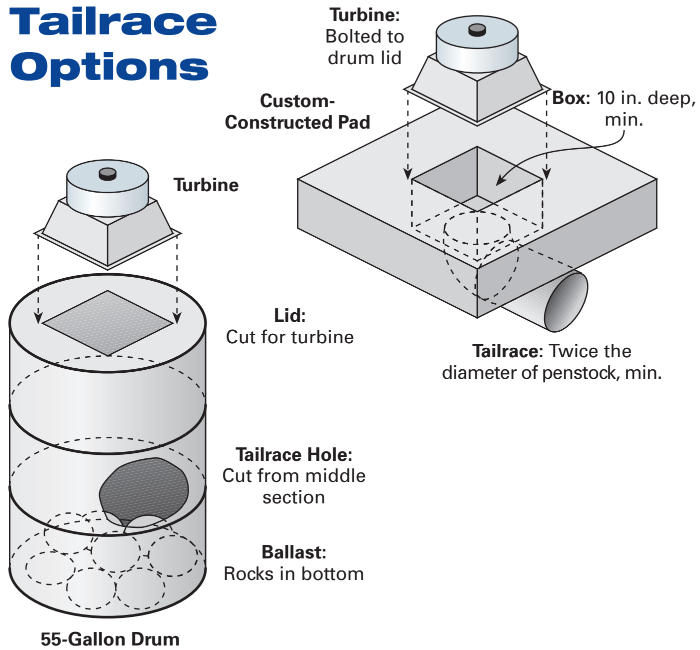
Mounts can have more elaborate masonry spillways or even drains that feed to a decorative water feature in the yard. Other times, the tail water can be used for a secondary purpose, such as filling a pond or irrigating a garden. Let your imagination be your guide, but remember that once you have extracted the energy for making electricity, the water will not be pressurized for other uses and gravity needs to take the water away freely.

The final consideration for hydro mounting is protection for electrical portions of the control panel. Though rain needs to be kept out, the unit should not be so well sealed that condensation becomes a problem. A roofed, three-walled structure for the turbine works great. One side is left open for easy access to the hydro plant. Although most permanent-magnet turbines are built for outdoor operation, they will last longer if protected from the elements. In terms of human resilience—an all-important factor to enable turbine maintenance—having a shelter makes repairs, flushing the penstock, and cleaning the turbine jets much more tolerable.

The components at the bottom: Thrust block, coupler, pressure gauge, cleanout valve, nozzle valves, turbine, and tailrace.

Courtesy www.microhydropower.com

Tailrace Options



Best Penstock Practices

For penstocks, the rules are simple—straight-as-possible, round sweeps, and steady elevation declines. Unfortunately, that's usually easier said than done. Often times, site constraints make it necessary to break or bend the rules. You should do what you have to do, but know that your system will be more vulnerable to performance and maintenance issues. Any low spots in the pipeline, for example, could become sediment traps that will occasionally need to be blown out by opening the pipe at the bottom and letting it run full volume. High spots in the penstock will create air pockets that will need to be bled. Finally, any bend in the pipeline will mean greater resistance to flow and reduce the energy available.

Include a pressure gauge in the pipe on the uphill side of the lower shutoff valve to help diagnose problems. A higher-than-normal reading usually indicates a plugged jet. A lower-than-normal reading can mean that the pipe or filter screen is plugged, or that there is not enough water available to the penstock. A pulsating gauge indicates turbulence, usually caused by running a higher flow rate than the penstock is designed for, which can result from installation errors, such as too many bends or an uphill run somewhere.

Select the right pipe, anchor it well, and keep it straight and simple. Follow these rules, and the penstock "engine" will serve you and your turbine well—and get the most energy out of your hydro system. And be sure to check out the next installment, where we'll take a look at the electrical and wiring aspects of your hydro system.

Access

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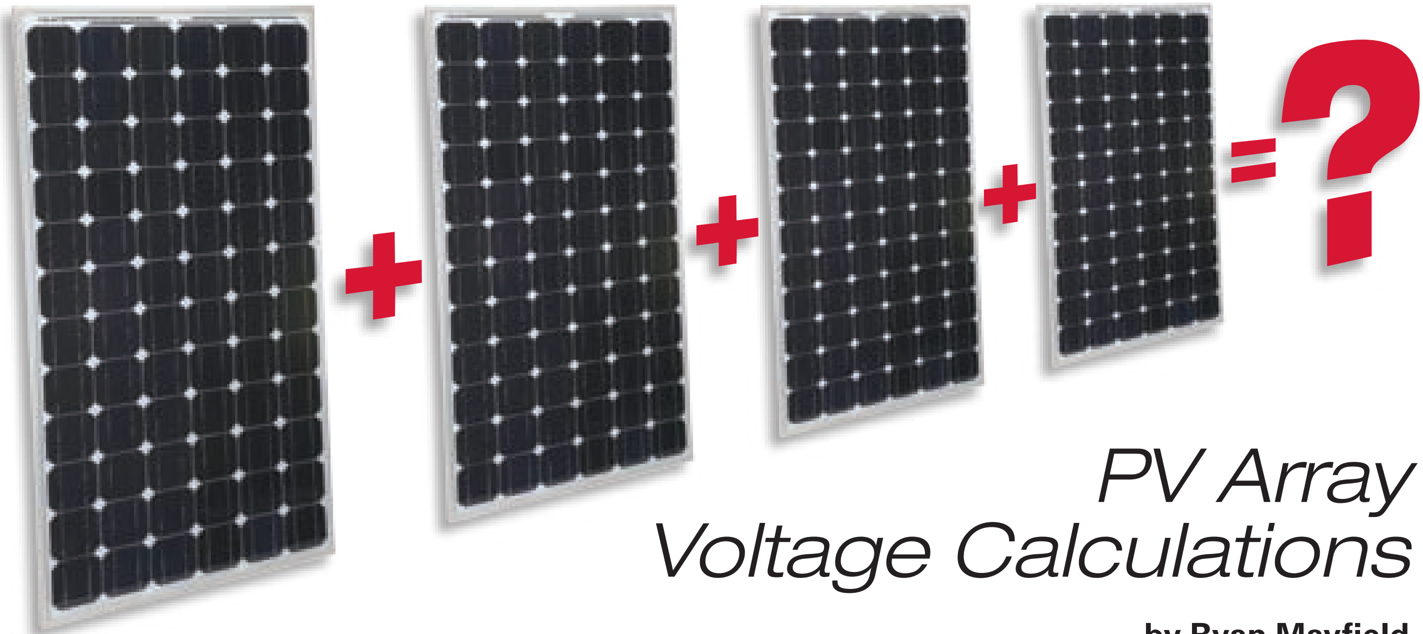
String Theory



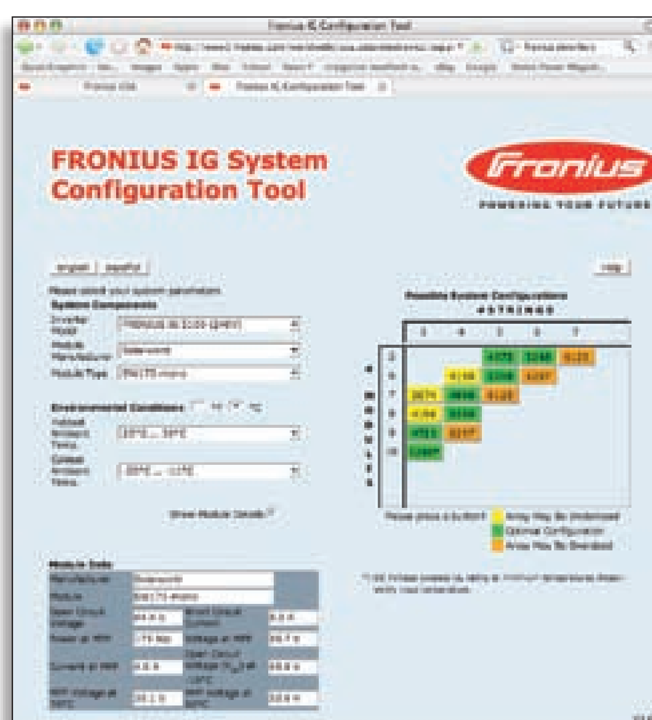
PV Array Voltage Calculations

by Ryan Mayfield

A decade or so ago, most PVs were designed with battery charging in mind. Module open-circuit and maximum power voltages fit into simple 12-volt nominal building blocks—one or more modules wired in parallel provided ideal voltage for charging a 12 V battery bank. Strings of two modules wired in series charged 24 V battery banks, and "high" voltage systems had four modules in series and operated at 48 V nominal. But as inverter and charge controller designs have evolved, the concept of designing systems in 12 V increments has faded.

Today, grid-direct batteryless inverters are designed for up to 600 volts open circuit (Voc). Several brands of maximum power point tracking (MPPT) charge controllers are able to charge a lower-voltage battery bank (12 to 48 V nominal) from higher-voltage arrays with open-circuit voltages of approximately 150 Voc. Even module design voltages have deviated from the simple 12 V building-block approach. First, 24 V nominal modules hit the market, and now many modules operate at voltages either above or below 24 VDC nominal. In fact, in most systems, the concept of PV array nominal voltage has been left by the wayside. Open-circuit voltage (Voc) and maximum power voltage (Vmp) are now the basis of PV array design.

The Fronius IG 5100 inverter has an operating voltage range between 150 and 450 VDC, and a maximum input voltage of 500 Voc.

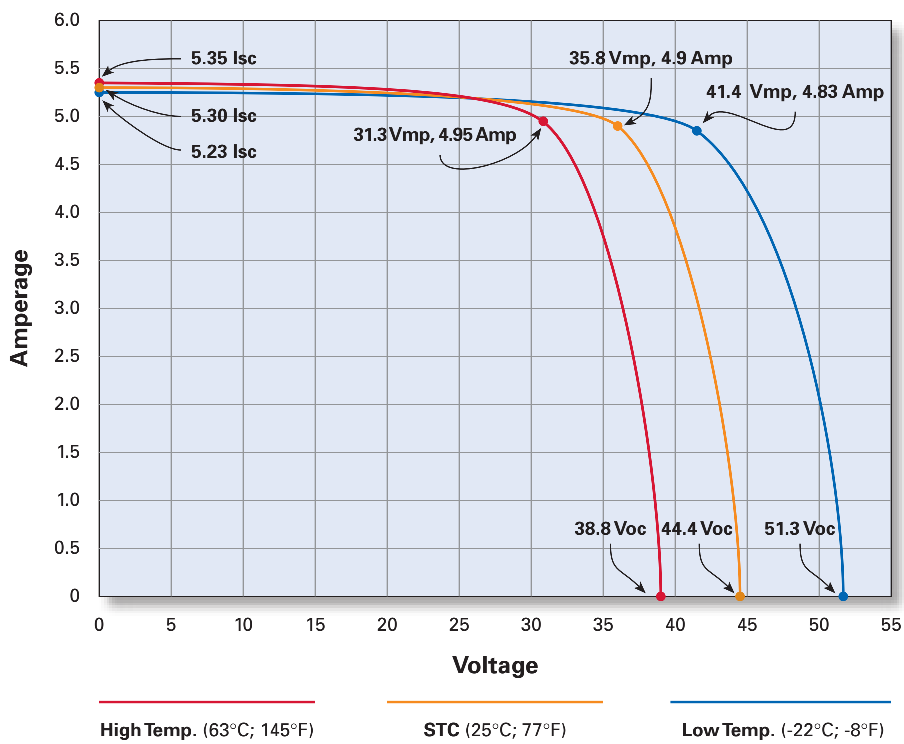


The Fronius string-sizing calculator is available online and for downloading.

String Sizing Considerations

A number of variables affect PV array voltage and performance. Module-specific operating characteristics, the number of modules in series, cell temperature, mount type, inverter or charge controller specifications, and the coldest historical temperature at your site all come into play. Most, if not all, high-voltage-string inverter manufacturers have online calculators to help system designers determine the maximum, minimum, and the ideal number of modules per series string for their equipment. Similar calculators have yet to be developed by all MPPT charge controller manufacturers, so system designers need to run their own calculations to determine an array's acceptable voltage range. While string-sizing calculators remove much of the math from system design, understanding how the calculations are made will help you better understand how a PV array functions day to day and season to season.

IV Curve per Cell Temperature



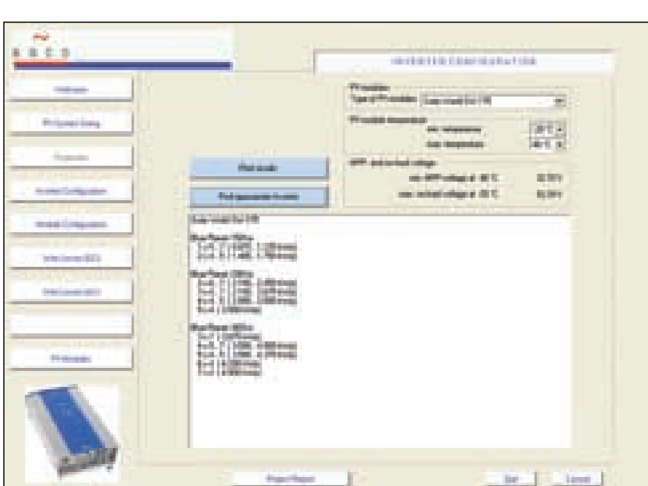
Temperature Effects & Array Voltage

A PV module's voltage is directly affected by its operating temperature. As module temperature increases, voltage decreases. PV module manufacturers rate a module's open-circuit and maximum power voltages at a standard test condition (STC) of 25°C (about 77°F). As module temperature rises above 25°C, the voltage drops. Conversely, if the module's temperature drops below 25°C, the module's operating voltage will be greater than its rating at STC.

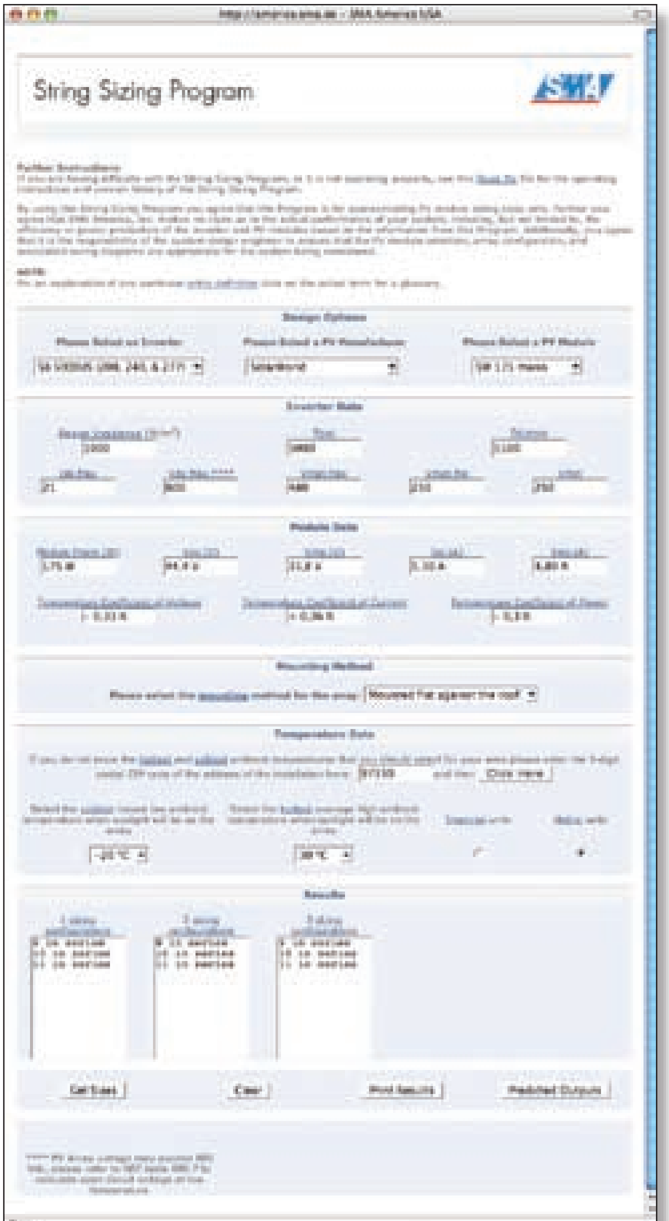
Because temperature has a significant effect on module output, PV manufacturers specify a module's temperature coefficient, which is represented as a percentage of voltage loss per 1°C above 25°C. A common temperature coefficient value for crystalline PV modules is -0.38% per degree Celsius; so for every 1°C above 25°C, the module temporarily loses 0.38% of its voltage. And for every 1°C below 25°C, the module voltage will increase by 0.38%.

Another approach to specifying the effect of changing module temperature is a voltage correction value—the number of volts per degree Celsius that the module will lose as its temperature rises above the 25°C reference point. For example, a crystalline module with a maximum power voltage of 34.8 volts might have a temperature correction factor of approximately -0.144 Voc per degree Celsius. These figures are provided on the module's specification sheets.

The Kaco 3601xi inverter has an operating voltage range between 125 and 300 VDC, and a maximum input voltage of 400 Voc.



The Kaco string-sizing calculator is one part of the system design software available for download.



The SMA online string-sizing calculator.

The SMA Sunny Boy SB7000US inverter has an operating voltage range between 250 and 480 VDC, and a maximum input voltage of 600 Voc.

It may not sound like much, but when the temperature values are applied, the combined effect can be substantial. For example, on a sunny summer day, module temperatures in a parallel-to-the-roof array installation will typically be about 35°C (63°F) above ambient temperature. If the module's temperature coefficient was -0.38%, for every degree Celsius in temperature rise array voltage will be reduced by this percentage. In this case, if the ambient temperature was 25°C (77°F), the module temperature would be approximately 60°C (140°F), and the actual array voltage would be about 13.3% below its rated value at STC.

Sizing to the Voltage Window

The power processing equipment connected to a PV array also has an allowable voltage range. This is true of high-voltage string inverters, battery-based MPPT charge controllers, and, less commonly, DC loads, such as well pumps that are directly connected to PV modules.

These components have both maximum Voc and minimum Vmp requirements. Together, these specifications represent the "voltage window" within which the components can operate. For example, a high-voltage grid-direct inverter might have a maximum Voc rating of 600 volts, and an operating voltage range or window between 240 and 550 VDC.

In many cases, inverters and charge controllers can be damaged if the array produces voltage greater than the maximum value of the equipment, which can happen in cold, sunny weather if the design voltage is too close to the maximum. In turn, if the array voltage drops below the minimum value due to elevated temperatures, inverter or controller power production will stop until the array cools and the voltage rises. Because of this, PV system designers need to account for both extremes of the voltage window to ensure that the PV system will perform in the full range of conditions.

For a particular piece of equipment, voltage correction factors must be applied to the array's assumed operating temperatures for the system's site. This information is one piece of the puzzle that will help determine the appropriate number of modules allowed in a series string.

It all boils down to choosing a string size that meets three very important parameters while trying to optimize a few more. You must satisfy a voltage window that, on the high end, is limited by the maximum open-circuit voltage that the inverter or controller can handle before you harm its electronics. On the low end, there are two limiting factors—the minimum MPPT voltage that the inverter can operate at and the minimum start-up voltage the inverter needs to have. If the maximum Voc and minimum Vmp values are correctly calculated and the array designed to these specs, the minimum start-up voltage will always be met.

Once you have satisfied these requirements, you'll still need to determine the appropriate array wattage to ensure you are

using the inverter or controller efficiently. Oversizing an array's wattage typically won't damage inverters or controllers, but a portion of the array's output will be dumped (wasted) as heat, and elevated operating temperatures may lead to shortening the operational life of the equipment. When sizing the array, you'll also have to stay within the inverter or controller's amperage limit, and size transmission wiring to keep voltage drop to a minimum. Finally, because PV module output is inherently temperature dependent, all of these parameters are moving targets, with cold and hot weather performance varying greatly, and array output current changing throughout the day as irradiance levels fluctuate.

Maximum Modules in Series

PV modules reach open-circuit voltage with very little irradiance striking them, approximately 200 watts per square meter. This can often occur within half an hour of sunrise, before the sun has the opportunity to warm the modules. And although the array will be at Voc and not producing any power, that voltage will be applied to whatever component it is connected to.

To determine the maximum number of modules allowable in series for a given piece of equipment, you'll need to determine array Voc at the coldest historical temperature where the array will be installed (see www.weather.com/common/home/climatology.html). You may need to adjust this value somewhat for your microclimate and elevation. The temperature used in this calculation is most often the record low temperature at the array location. To determine the adjusted open-circuit voltage (Vadj) for the PV module, use the following equation:

Vadj = Voc x {1 + [(Tcell – Tstc) x temperature coefficient]}

Where:
Vadj is the adjusted voltage for the module;
Voc is the STC open-circuit value for the module;
Tcell is the module's cell temperature in degrees Celsius (the cell temperature in this situation will be the same as the coldest historical ambient temperature at the site);
Tstc is the STC temperature value for the module, generally 25°C; and
Temperature coefficient is the percentage loss of voltage specified for the module.

To determine the maximum number of modules allowed for a piece of equipment, the adjusted voltage must be divided into the equipment's given maximum voltage (Vmax). Round down to the next whole number to ensure the array's voltage will not exceed the maximum value.

Minimum Modules Needed Per String

After calculating the maximum number of modules allowable per string, verify the minimum number of modules needed. The array needs to be sized so that when the system is operating at high temperatures, the array voltage remains above the minimum voltage-window threshold to ensure continued operation. To do this, you'll need to determine the array voltage (Vmp) based on its typical operating temperature during the hot summer months.

Example String-Sizing Calculations

Location & Climate

Location: Corvallis, OR
Record low: -22°C (-7°F)
Average low: 1°C (34°F)
Average high: 28°C (82°F)
Record high: 42°C (108°F)

Photovoltaics

Module: SolarWorld 175 W
Voc: 44.4 V
Vmp: 35.8 V
Temperature coefficient: -0.33%/°C
Mount type: Parallel-to-roof mount (4 in. from roof surface to back of module)

Equipment

Inverter: PV Powered 5200
Maximum Voc: 500 VDC
Minimum Vmp: 240 VDC

Calculations

Step 1. Calculate the adjusted voltage for low temperatures.

Vadj = 44.4 V x {1 + [(-22°C – 25°C) x -0.33%/°C]}
Vadj = 51.3 V

Determine the maximum number of these modules in series for this inverter at this location:

Maximum number per string:
Component's max. Voc ÷ Vadj for low temperatures

500 VDC ÷ 51.3 V = 9.7 modules

Round down to the next whole number—in this case, nine modules is the maximum number in series.

Step 2. Calculate the adjusted voltage for high temperatures.

Vadj = 35.8 V x {1 + [(28°C + 35°C – 25°C) x -0.33%/°C]}

(Note the additional temperature—35°C—due to the racking method.)

Vadj = 31.3 V

Determine the minimum number of these modules in series for this inverter at this location:

Minimum number per string:
Component's min. Vmp ÷ Vadj for high temperatures

240 VDC ÷ 31.3 V = 7.7

Round up to the next whole number—in this case, eight modules is the minimum number in series.

Comparing these calculations to those for other equipment will determine if you may be better off with a different combination of equipment. The minimum value calculated should always be carefully considered and is rarely the best choice. In this example, if strings of eight modules are used, the resulting Vmp on an average day will only be 250.4—precariously close to the low value (240 VDC) of the sample inverter's operating window.

The Xantrex GT5.0 inverter has an operating voltage range between 240 and 550 VDC, and a maximum input voltage of 600 Voc.

The Xantrex online string-sizing calculator.

Racking Correction Figures

Two things—array mounts and operating temperatures—are important in evaluating the array's operating voltage. The type of module mounting used influences heat dissipation—some methods allow for better airflow than others (see "Rack & Stack" in *HP123*). And although there are methods to estimate the module's operating temperature based on mounting method and irradiance, it is common to use industry-accepted factors based solely on mounting methods. These values are added to the ambient temperature to estimate the array's operating temperature.

The racking correction temperatures are applied to the highest average ambient temperature at the array's location:

- Parallel to roof (<6 in. standoff): +35°C
- Rack-type mount (>6 in. standoff): +30°C
- Top-of-pole mount: +25°C

The highest temperature used is generally the average high temperature during the summer months, although some designers prefer to use the annual record high temperature for this calculation. Using the annual record high temperature for the calculation is a more conservative approach that ensures that the array will operate in all conditions it is subjected to without dropping below the inverter's voltage window.

After the module's voltage is corrected for maximum temperature, this value is divided into the component's minimum voltage window. The result is a fractional value that must be rounded up to the next highest whole number, since at times the array will be operating at temperatures higher than the average value used.

When determining the minimum number of modules in series, designers need to be careful not to design a system that will normally operate at the very bottom of the voltage window. An array's voltage that consistently drops to or near a component's minimum window on "average" days increases the possibility of reduced energy output on days that exceed the average temperature. And, while PV modules are built to last, some degradation occurs over time. This is primarily due to moisture ingress that gradually corrodes a module's internal electrical connections, creating higher resistance that, in turn, results in lower operating voltages. In extreme cases, this voltage degradation could amount to as much a 1% annual drop in module voltage. So you'll also need to account for this over the array's lifetime. Given these considerations, designing string sizes well above the minimum acceptable voltage level is sound system design.

Access

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Online String Calculators:

Fronius • www.fronius-usa.com

Kaco • www.kacosolar.com

PV Powered • www.pvpowered.com

SMA America • www.sma-america.com

Solectria • www.solren.com (charts only)

Xantrex • www.xantrex.com

Pumping Water with Sunshine

by Erik Lensch

One of the simplest and most economical uses of solar energy is for pumping water. With advancements in pumps and pump controllers, solar water-pumping systems have become fairly easy to install, operate, and maintain.

If you live beyond the reach of the grid, or have a remote pumping need like irrigation or livestock watering, a solar-electric pump system can be a solution that's reliable and sustainable. This article covers the basics of several types of PV-powered pumping systems, including array-direct, battery-based, and both pressure-tank and high-volume water storage.

Solar Pump Types

There are two basic types of solar water pumps—submersible and surface. In this article, we'll be looking primarily at submersible pumps used to deliver potable water for domestic use. A submersible pump is usually positioned in a well, although there are instances where a stream or pond is used as the source. Unlike surface pumps (installed above the source's water level) that *draw* water up from shallow sources like a pond, submersible pumps *push* water up to a holding tank or pressure tank. The right-sized submersible can pump water out of deep wells, up to 1,000 feet or more. Most models are durable and can tolerate water with relatively high levels of silt.

Submersible pumps break down into three main categories—centrifugal, helical rotor, and diaphragm. **Centrifugal pumps** have an impeller that spins at high speeds, producing a high flow of water. Because the spinning rate is high, the flow rate is generally high. However, pressure, and therefore the amount of pumping height (head or lift) that can be attained, is usually lower than in other types of pumps.

Higher lift can be achieved with **helical rotor pumps** (a type of "positive displacement" pump), which will also provide a flow rate great enough to meet most household demands. With these pumps, picture the water being sent out of the pump body in small "packets" that are pumped very quickly to provide a constant flow. An analogy that is sometimes used is that of a spiral staircase in a sealed shaft, with the staircase spinning around very quickly. Each "stair step" lifts water toward the top of the pump, then to the pump outtake, and eventually out the top of the well. Since the water needs to be carried through the pump body, the result is a lower flow compared to centrifugal pumps. However, with its higher pressure, a helical rotor pump can deliver water against higher heads.

Depending on the model, submersible **diaphragm pumps** (another type of positive displacement pump) can pump up to about 5 gpm from shallow wells (under 100 feet), or lower volumes from well depths down to approximately 250 feet. A 4-inch well casing is typically required. Although these pumps are less expensive than centrifugal or helical pumps, they require significantly more maintenance.

Different models of submersible pumps are designed to run on AC, DC, or both. To simplify wiring, off-grid residences with AC PV systems often rely on an AC submersible pump. It's important to note that most "AC" pumps actually utilize brushless DC motors. In this case, the pump contains electronics that allow it to be powered by a standard AC source like an inverter or the grid. The pump is just another AC load to be considered when sizing the system's battery bank, inverter, and charge sources. Many AC pumps will require two or more times the power (wattage) to start the pump than is needed when the pump is running, and the system's inverter needs to be able to handle this extra start-up load. The Grundfos SQ series of pumps is very popular in the off-grid world. These pumps have no start-up surge, and have a great reliability record in the field.

But DC submersibles take more efficient advantage of battery-based PV systems compared to AC pumps. AC pumping includes DC-to-AC conversion losses: A PV array's direct current is stored in batteries before being converted to AC by the system's inverter, which in turn, powers the pump. Inefficiencies associated with the charging and discharging of batteries can account for losses of 5% to 10% or more, depending on the age and condition of the battery pack. And with an inverter average conversion efficiency of approximately 85%, an AC pump will require approximately 20% to 25% more PV energy to pump the same amount of water compared to a DC-direct pump.

A pump controller like this SunPumps PCB-180BT balances PV voltage and current to optimize pump performance throughout the day.

Submersible Pump Types

A DC submersible diaphragm pump (middle) and a centrifugal pump (right), with controller (left), by SunPumps.

A helical rotor pump (middle) and a centrifugal pump (right), with controller (left), by Lorentz.

Component Considerations

For either PV-direct or battery-based solar water pumping, the following design practices can ensure a top-notch system that maximizes your investment.

Site Right. For optimal performance, the array must be free of shading during the day and must be facing as close to true south as possible. For most residential water-pumping systems, the modules are set at a fixed tilt. But for applications that require a lot of water pumping during the summer, like irrigation, a sun-tracking PV module mount can maximize power production and pumping.

Trackers keep the modules perpendicular to the sun as it moves through the sky, providing more power to the pump over a longer period of the day. In the summertime, a tracked system with a clear horizon-to-horizon solar window can provide 20% to 40% more water than a fixed array.

Minimize Voltage Loss. To limit wiring voltage loss and minimize the length and the gauge of wire needed, locate the PV array as close to the pump or battery bank as possible. The greater the distance from the PV modules to the pump, the greater the voltage drop. Too much voltage loss can significantly reduce the amount of water pumped, and in some cases may be so great that the pump will not operate effectively.

Voltage loss should not exceed the accepted standard of 2%. For long distances, wire size must be increased, at additional expense. With the price of copper at an all-time high, it's usually cost-effective to locate the array as close to the pump or battery bank as possible. Your system designer can provide the wire-sizing calculation for you, or you can use software provided by the pump manufacturer.

Free Flow. Pipe friction is another important factor in optimizing pump production. The greater the distance between the pump's outtake and the delivery point, the greater the flow restriction from pipe friction. Much like voltage drop can be mitigated with larger wire size, flow restriction can be reduced by increasing the pipe size or reducing the distance. For household use, 1.25-inch- or 1.5-inch-diameter pipe is typical. However, if the distance exceeds 500 feet or the flow rate is expected to be unusually high, consider increasing the pipe diameter to 2 inches to keep friction losses down.

Pump Protection. To regulate flow, pressurized systems use a pressure switch. If a holding tank is used, a float or level switch turns off the pump when the water rises to a certain level. Some pumps require a "reverse-acting" pressure switch. Most pressure switches operate by closing the contacts when the pressure has risen to a preset point. Conversely, in a reverse-acting pressure switch, the contacts open when the pressure falls to a certain level.

Just as important is providing a shutoff mechanism for the pump. Damage can occur to the pump if it pumps against "shutoff" head when the holding tank is full and there's no overflow pipe or float switch in place. And to avoid damaging the pump if the water source runs dry, use dry-run protection (a water-level sensor) at the source. Some pumps have this built in, so check a given pump's specifications.

Under Control. All submersible water-pumping systems should have a controller between the power source and the pump. In PV-direct systems, the control can be as simple as using a linear current booster (LCB). An LCB optimizes array voltage and current, maximizing the volume of water pumped and helping the pump start sooner in low-light conditions. More advanced controllers include pump motor speed-control and low-water cutoff circuits. Some even provide information related to the system status, including how many watts the PV modules are producing, and can be helpful for system troubleshooting. Most pump manufacturers offer one or more controller options designed to be used with their pump model.

Arresting Lightning. Proper system grounding will usually protect the pump and control. But some manufacturer warranties also require a lightning arrestor be installed. As with any PV system, the array and its modules should be properly grounded. While a direct lightning strike will likely damage the controller, the pump may survive if the system is well-grounded.

Lorentz manufactures a range of pumps, some of which operate at up to 200 volts open circuit. Centrifugal DC pumps manufactured by SunPumps operate at up to 245 Voc. They offer models that can pump 4 gpm from wells up to 650 feet deep, or up to 250 gpm from shallow wells or surface water sources. SunPumps and Shurflo also make less expensive diaphragm pumps that can be good choices in array-direct (batteryless DC from PV modules) applications for domestic, irrigation, or livestock watering, provided that the water is relatively silt free.

Grundfos manufacturers the SQFlex, a centrifugal pump that can run on either AC or DC power—no special equipment is needed to make the switch. In DC systems, the pump only requires 30 VDC to get going, but the pump's 300-volt open-circuit limit allows the array to be wired at higher voltages, decreasing both wire size and cost. With the addition of a generator interface box, the pump can be switched to accept AC power from a generator during sunless periods.

A Lorentz PS150 Boost diaphragm surface pump is typically used to pressurize water systems.

Solar Pumping Systems

There are three general solar water-pumping system types. Your best solution will depend on elevation changes at your site, whether there are inverters in your system, and how much flexibility you have when it comes to *when* you pump water.

Array-Direct to Elevated Storage. The most efficient solar water-pumping systems are PV-direct without batteries. This classic off-grid pumping solution connects a DC submersible pump directly to the PV array. One additional component, either a controller or linear current booster (LCB) wired between the PV array and the pump, optimizes the relationship between array voltage and current to maximize the amount of water pumped under varying sunlight conditions. When the sun is shining, the pump moves water to a tank located above the water's point of use. (For potable water, use only drinking-water-grade tanks.) For each 2.31 feet of elevation, there will be 1 psi of water pressure. Many household water supplies operate at about 40 psi (though down to 20 psi can often work), so locating the storage tank about 100 feet higher than the point of use will provide adequate water pressure.

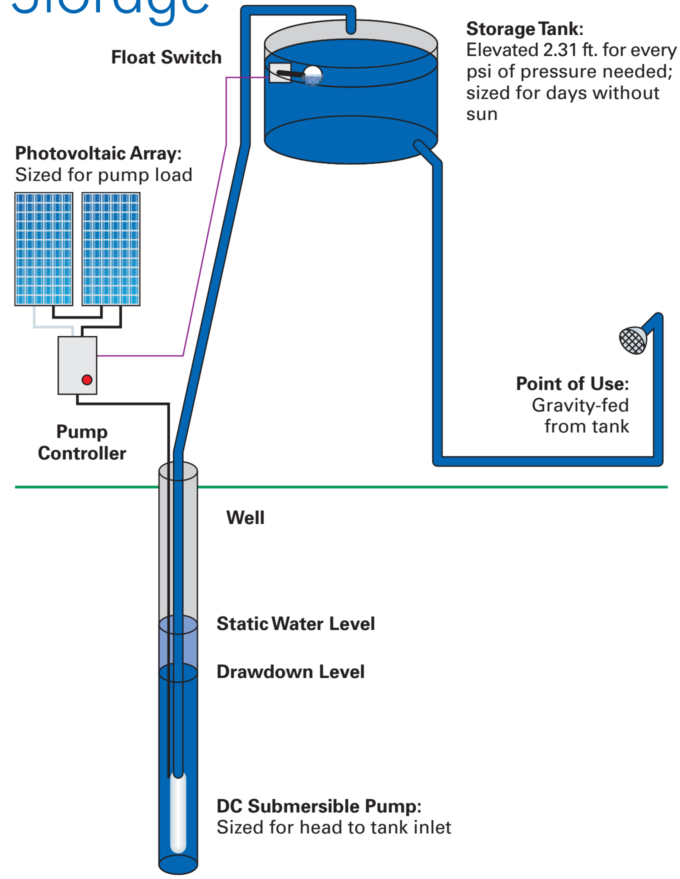
The beauty of these systems lies in their simplicity. The tank acts as a large "battery," storing the pumped water for later use. And since the elevation of the tank provides the needed water pressure, no pressurizing pumps or pressure tanks are required. For household domestic water systems, I recommend sizing the storage tank to hold at least five days' supply of water to cover those inevitable periods of cloudy weather. If properly sized, the pump will slowly fill the tank when the sun is shining. When the sun isn't shining, the pump doesn't run. It does not damage the pump to go on and off during the day as clouds pass over.

Other advantages of PV-direct pumping are the efficient use of PV energy (no losses to battery charging or inverter conversion) and the potential for reducing generator run-time. Off-grid system users often limit generator-based charging (and the associated noise, pollution, and fuel expense) by waiting to perform energy-intensive activities—like running the vacuum or shop tools—until there's plenty of solar energy available. This limits battery bank depth of discharge to extend battery life. In properly sized PV-direct to storage tank systems, several days' worth of water will be stored in the tank. During cloudy periods, you will already have pumped the water you need, and the generator won't be needed to keep the batteries topped off while pumping.

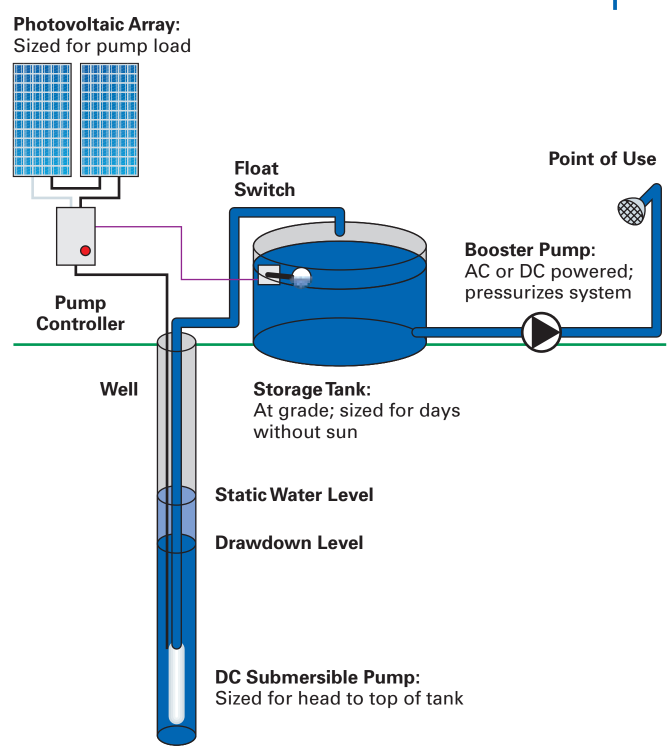
Array-direct to elevated storage systems will save you money in the long run and add more flexibility to your off-grid energy lifestyle. But keep in mind that the additional expense of the tank and for trenching the pipeline deep enough for freeze protection can make these systems more expensive up front than other options.

Array-Direct to Storage Tank with Pressure Pump. If you like the efficiency of DC pumping and want stored water at your disposal, but don't have enough of an elevation change on your property for a gravity system, there are still options.

Array-Direct to Elevated Storage



Array-Direct to Storage Tank with Pressure Pump



A PV-direct DC pump can be configured to fill a storage tank near its point of use, and an additional DC or AC booster pump can be installed at the tank to pressurize the water. This solution gets the heavy lifting (from the well to the storage tank) done whenever the sun's shining, and limits energy use during cloudy periods to a smaller pressure pump that activates via a pressure switch when water is used.

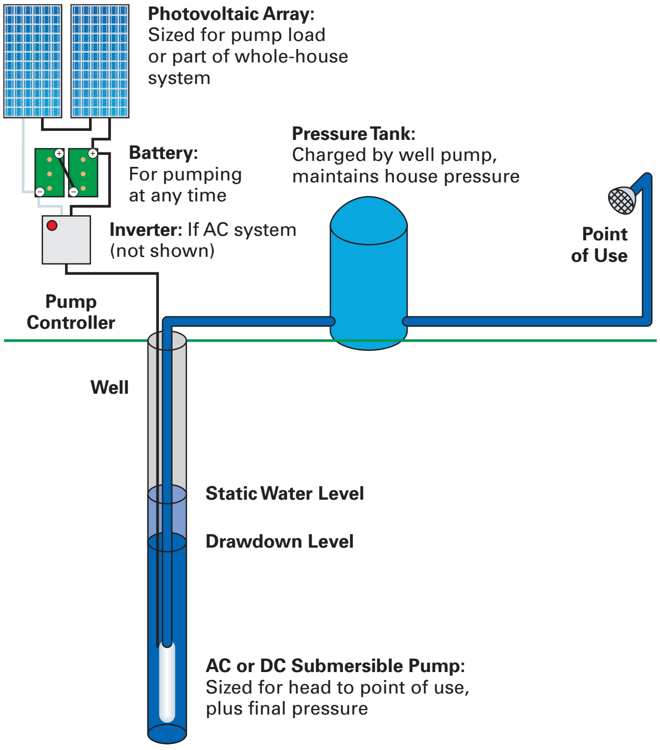
While this configuration gives you more flexibility to choose when you consume the energy required to pump well water, the up-front costs of the storage tank and additional pressure pump add to overall system cost and installation complexity.

Pump to Pressure Tank. The most conventional of the three pumping systems described uses an AC submersible pump to push water directly to a pressure tank. A DC pump sized to meet the site's flow rate requirements can also be run directly from the battery bank, eliminating inverter conversion losses. A standard pressure switch activates the pump when the pressure in the tank drops below a set level, say 30 psi. At 50 psi or so, the switch's upper-limit shuts off the pump. Instead of a 1,200-gallon or larger water storage tank, a smaller 40- to 60-gallon pressure tank is all that is needed.

Compared to the systems described earlier, pump-to-pressure tank systems usually have the lowest up-front component costs (there's no large storage tank or secondary booster pump), and pump installers everywhere are familiar with these systems. But they may not be familiar with the limitations of battery-based power sources (pump surge, inverter capacity issues, and the like), so pay close attention to the pump's operating characteristics and seek out an installer familiar with off-grid pumping systems whenever possible.

Installation of a Grundfos SQFlex submersible pump.

Pump to Pressure Tank



For off-grid installations, the downside of pump-to-pressure tank systems is that the pump will need to come on during most water draws. During cloudy weather or overnight, the energy to repressurize the tank will come from your battery bank. Batteries like to be fully charged, and the deeper you discharge them and the longer they stay in that state, the shorter their service life will be. Another consideration is that, compared to array-direct systems with high-volume storage, increased generator run-time during cloudy weather will be a necessity.

Access

Erik Lensch is the owner of Innovative Solar Solutions (www.innovativesolar.com), based in Charlotte, North Carolina. Formerly SC Solar, the company has been designing and supplying solar water-pumping systems since 1999.

Submersible Pump Manufacturers:

Conergy • www.conergy.us • DC pressure & surface pumps

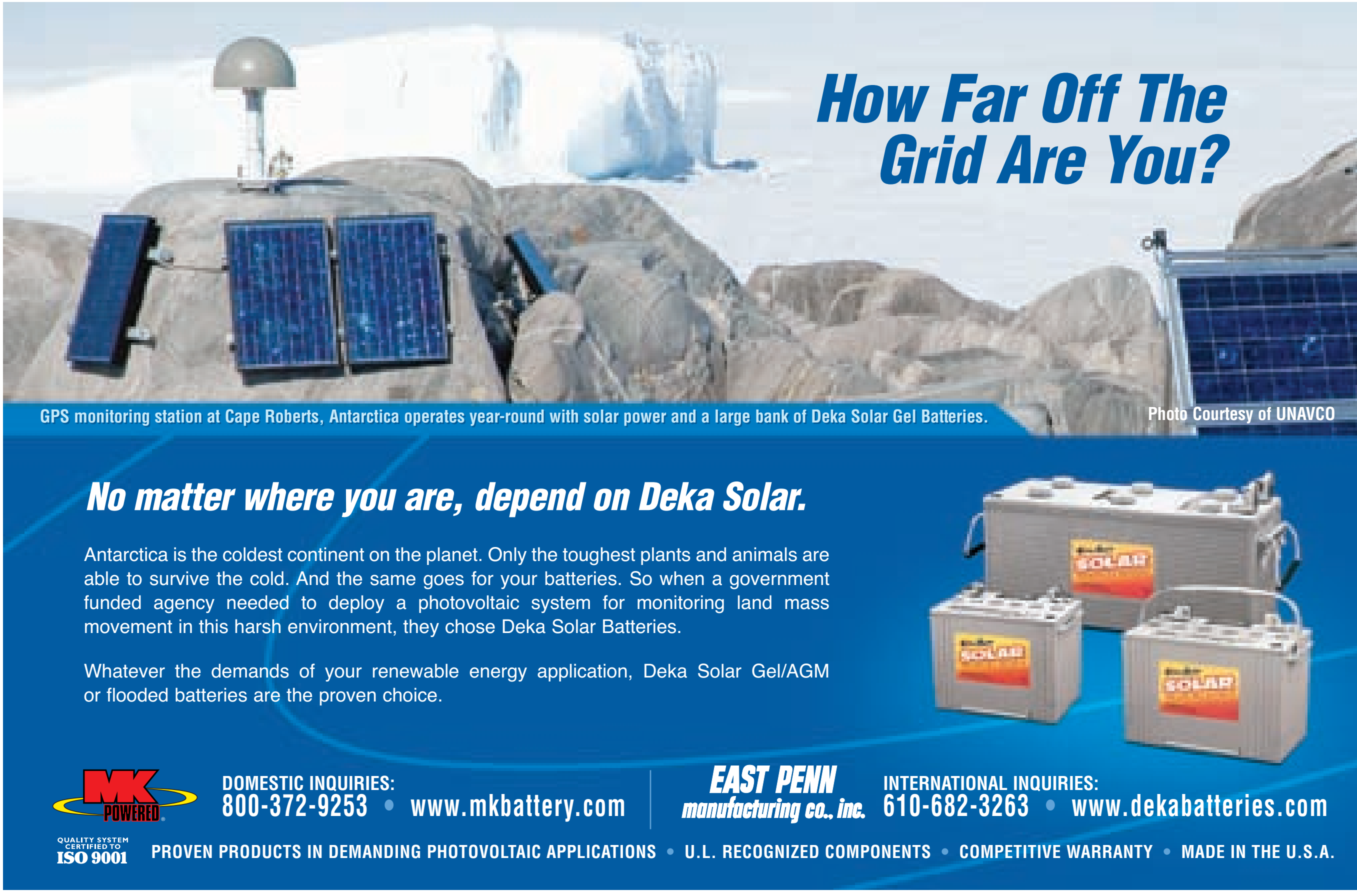
Grundfos • www.grundfos.com • AC & DC/AC submersibles

Lorentz • www.lorentz.de • DC pumps & solar trackers

March • www.marchpump.com • AC & DC pressure pumps

Shurflo • www.shurflo.com • AC & DC pressure pumps & DC submersibles

SunPumps • www.sunpumps.com • DC pressure & submersibles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GPS monitoring station at Cape Roberts, Antarctica operates year-round with solar power and a large bank of Deka Solar Gel Batteries.
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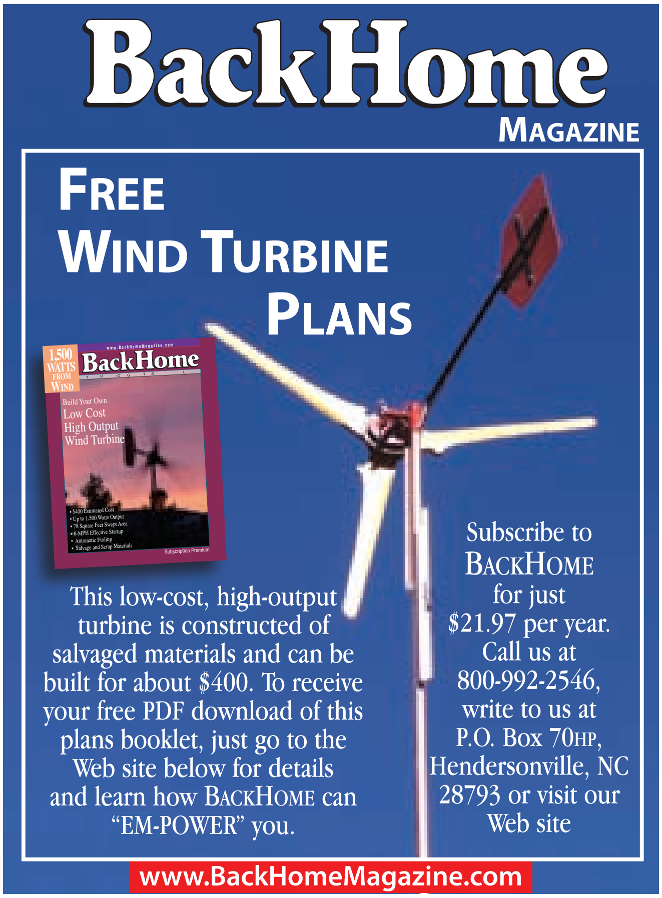
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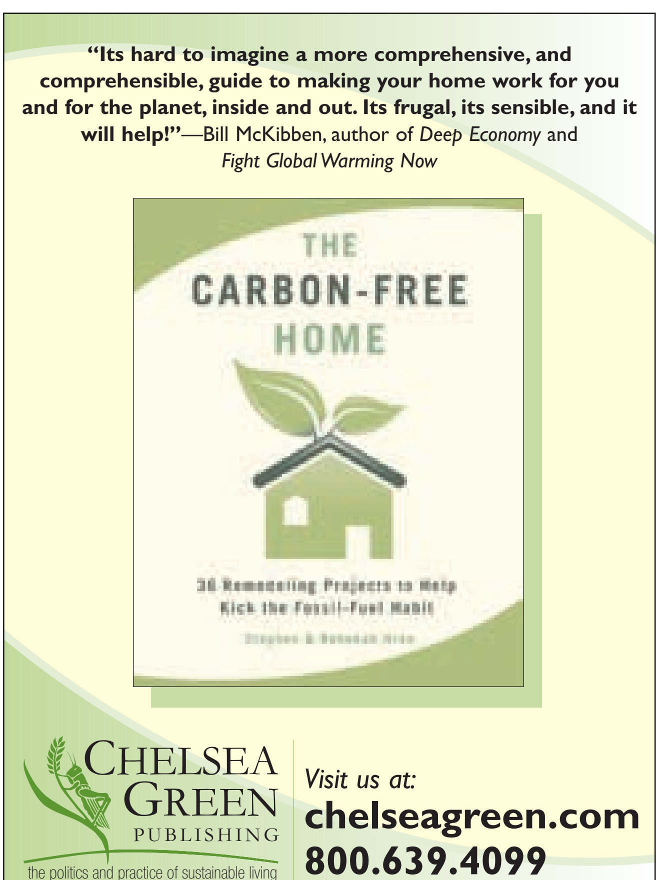
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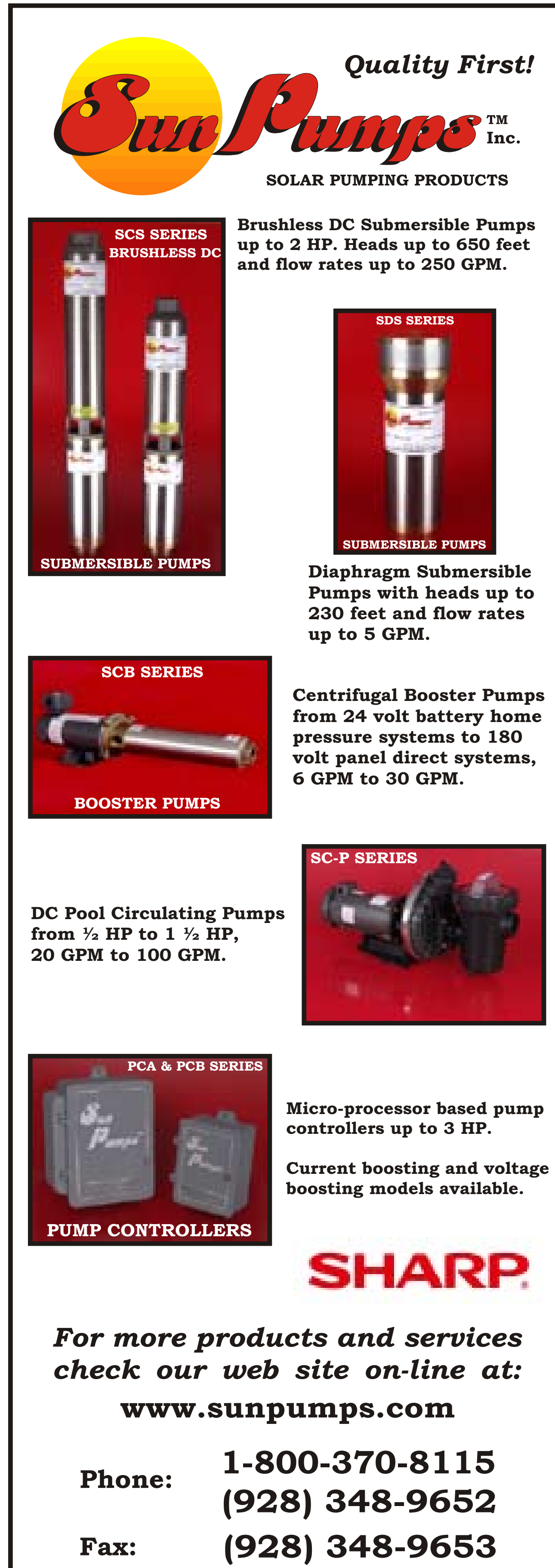
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GOING TO ZERO

by John Patterson
photos by Suzanne Olsen

For 28 years, my company has been helping its customers meet their energy needs with the power of the sun, but only recently, with our move into a new headquarters, have we been able to walk our talk by operating in a net zero-energy facility. When I started this business, working with only a part-time plumber, I never would have imagined that the company would grow to a team of more than 20 employees. With each new employee, I've become more and more aware of the energy impact of our day-to-day operations.

In 2002, after almost ten years working out of a solar demonstration home that I had built near downtown Portland, Oregon, I moved our offices into a nearby commercial facility. Though the building suited our operations in many ways, it had one major drawback: The landlord would not allow us to put PV or solar hot water systems on the roof.

Because I'm in the solar business, I dreamed of housing our offices and warehouse in an energy-efficient building with solar systems providing 100% of our energy needs. Though I initially had mixed emotions about starting over in a new building, I began to see the move as an opportunity—the first step in achieving zero net-energy use.

Of course, while energy efficiency was a high priority, I had other considerations too—namely, I needed a loading dock. At our previous location, wheeling a 14-foot solar collector down the hallway, out the door, and hoisting it up onto the truck while cars sped by only a few feet away was precarious to say the least. So when I found a south-facing building with loading docks, it was a double bonus. The fact that the building was in a highly visible spot near Portland International Airport made it that much more appealing. Plus, the location was central to the city and Vancouver, Washington, where we perform most of our installations.

The 10,000-square-foot building had been built as a sandblasting facility in 1950. More recently, it had been used by a trailer manufacturer, with a portion of the space divided into offices. The building was sturdy as a rock and had both single-phase and three-phase electricity. On the other hand, it was filthy, and the low ceilings and lack of windows in the office area made it dark and gloomy. For six months, I resisted purchasing the building just because I dreaded the work that I'd need to do to get it into shape.

In December 2005, I finally gave in. The plan was to expand the existing office area, which had been sectioned into small rooms, to accommodate our showroom. The remaining 8,000 square feet with 16-foot-tall, open-truss ceilings would become a warehouse, shop, and production area.

Getting Comfy with Efficiency

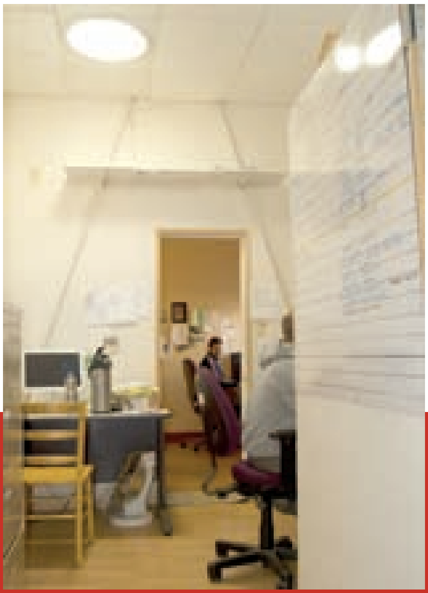
From an energy and comfort standpoint, the building was a disaster—and I wanted no part of the $1,500-per-month energy bills that the previous occupant reported. The office area had only two windows. The carpet was more blackish-gray than beige from years of hard wear and greasy boots. The whole space smelled like a mechanic's garage. Light-defying walnut paneling engulfed the four office walls. The ceilings were oppressively low and dingy.

Improving Insulation. The only insulation in the building was ancient R-11 fiberglass batting haphazardly placed above the false ceilings in the office area. The first order of business was to blow an 18-inch-thick layer of new cellulose insulation right on top of the fiberglass. This filled in many of the voids and raised the insulation value in the attic to an estimated R-50.

The building's exterior walls are 1-foot-thick concrete. The interior wall surface was furred with wood nailers and covered with paneling. We attached R-16 rigid-foam insulation sheets directly over the existing walls and installed new drywall over that. Though the layering reduced the size of our already-small offices, the added insulation made all the difference in comfort.

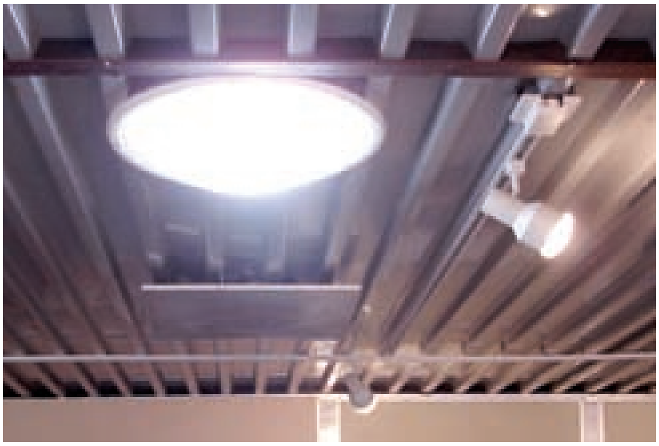
Next, we searched for air leaks. We sealed all the ducts, replaced broken window panes, and weather-stripped the outside doors. Because all the electrical outlets and switches had to be extended 2.5 inches to accommodate the thicker walls, we even sealed out any drafts around the boxes with insulation pads specially made for this purpose.

Lighting Strategies. The building's only natural light came from a bank of inoperable, steel-framed, single-pane windows



Natural sunlight, provided by tubular skylights, brightens the office space.

Glass blocks, filled with water and dyes, are part of the showroom's daylighting strategy.



Tubular skylights bring sunlight into interior spaces to reduce daily lighting loads.

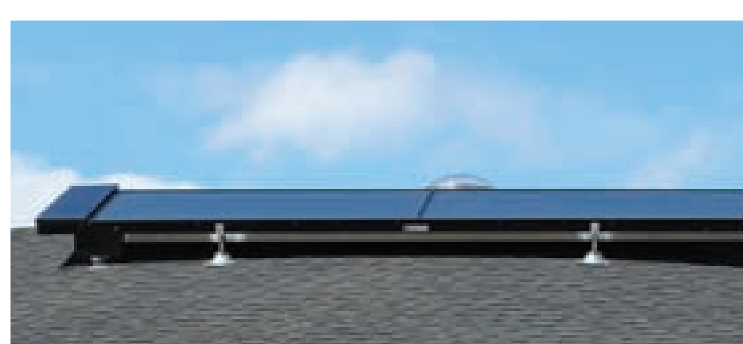
on the south and west walls. A fresh coat of light-colored paint covered dark, ugly interior walls and helped to brighten the office space some, but the building needed serious help in the lighting department. We swapped out the existing *10-kilowatt* lighting system—40 industrial light fixtures drawing 250 watts each—with industrial-sized tubular skylights, reducing the need for supplemental lighting during the day. Eight tubular skylights provide 90% of the lighting for the shop/ warehouse space and office during business hours.

Next, we added two tube-fluorescent fixtures for task lighting in the production area. For our most creative lighting project, we fit 1-foot-square glass blocks—filled with water for thermal mass—into the frames of a permanently locked, south-facing garage door that had been covered with drywall by the previous owner. For an interesting and colorful effect, we added yellow and orange dye to the water in some of the glass blocks.

All of these upgrades dropped our lighting load from 80 KWH to approximately 2 KWH per day, reducing our lighting costs by $240 per month. The skylights cost about $1,000 each, installed ($450 materials; $550 labor). At present electricity rates, it'll take us less than three years to recoup our costs.

Solar Water Heating. Within a year of moving into the building, we installed a solar water heating system and removed the backup electric water heater. Solar energy now provides 100% of the building's hot water, which serves two lavatories and two showers in the bathrooms. The system features a 56-square-foot thermal collector typically suited for a family of four. We located the solar storage tank in the showroom area so visitors can observe the water temperatures from the solar collectors—typically 140ºF in the summer and 80ºF in the winter. Even on the cloudiest days, visitors are pleasantly surprised to see the results of the system's PV-powered pump (a 12-volt DC Hartell pump directly powered by a 36 W module) in the glass flow meter.

The storage tank (left) and the hot water collectors with the module for the DC pump (right) make up the solar water heating system, which provides 100% of the building's hot water.



Space Conditioning. The mass of the slab-on-grade concrete floors in the building help moderate interior temperature swings. In the summer, the cool soil below the concrete floor tempers summer temperatures, while an awning shades the south-facing side of the building and prevents the summer sun from charging the concrete floor mass. As a result, our air conditioning unit is never used. On sunny wintertime days, the concrete absorbs solar energy, providing some offset for the electric air-source heat-pump system that serves the office space.

To improve the efficiency and operation of the heat-pump system, which was installed in the 1950s, I hired an HVAC contractor to inspect and service the equipment. He inspected the ducts, sealed air leaks, and replaced the dirty, blackened filter that looked as if it was original to the system. For added conservation, I installed a programmable setback thermostat.

Heating 2,000 square feet of segregated space efficiently takes some creativity and staff buy-in. Employees dress warmly in the winter, when the thermostat remains at 65°F during work hours. As needed, a 1,000 W radiant electric heater supplements the main heating system in the colder back offices. Overnight, the programmable thermostat allows interior temperatures to drop as much as 20°F. But because the functional mass of the concrete floor tempers heat loss through the night, the space reheats quickly—about an hour after the thermostat turns on the heating system in the morning.

The 8,000-square-foot warehouse is mainly used to store vehicles and renewable energy equipment inventory, so heating and cooling it is less of a priority. In the winter, which tends to be mild and mostly overcast, another 1,000 W electric radiant heater keeps temperatures tolerable in a production area. In the summer, two solar attic fans help by drawing hot air out.

Running the Numbers

After almost two years of tightening our energy belts and making efficiency upgrades, we were ready to calculate what it would take to reach net zero-energy usage. Our utility, Pacific Power, made it easy by providing a bar graph with the average daily KWH consumption for each month of the year. Upon poring over a year's worth of utility bills, we determined that our PV system would need to average at least 23 AC KWH per day to offset our usage.

From my experience, this load was on par with that of a highly efficient, all-electric home with passive solar design and solar hot water, and in which occupants practice energy conservation. In our case, besides space heating, we power one laptop and four desktop computers, a photocopy machine, a security system, and a dozen or so 15 W compact fluorescent lights in the office and showroom. We also have a total of six T-8 fluorescent tubes (32 W each) at task-lit stations in the production area. On a typical day, there are also six cordless-tool battery chargers plugged in.

Once we determined the load, it was time to size the system. Peak sun is a standard measurement of the sun at its brightest, and varies depending on the location's weather, latitude, and other factors. One peak sun-hour is equivalent to 1 KWH per square meter per day. In other words, a 100% efficient solar module that's 1 square meter in size would produce 1 KWH per hour under the best circumstances—on the brightest day at high noon, with the PV module perpendicular to the sun and at a time of year when the sun is passing through the least amount of atmosphere. Of course, PV modules are really in the 11% to 19% efficiency range, but you get the picture.

Most inhabited places have between 3 and 7 peak sun-hours per day. To calculate peak sun-hours in our location, we used the University of Oregon Solar Radiation Monitoring Laboratory's data. According to their analyses, average peak sun-hour equivalents for a fixed PV array in Portland are 3.9 hours per day. This assumes a true-south orientation, no shading, and a 30-degree tilt.

We elected to mount the modules at a 15-degree tilt to aesthetically fit them to the space we had. The shallower angle reduces performance by about 4%, but the concession for the array's more streamlined appearance was worth it. We also recognized that there would be about 5% in losses to convert DC to AC through the inverter, and an additional 1% voltage drop through the wires carrying the solar-spawned electrons. This added up to 10% in reductions for our planned layout, leaving us with the equivalent of 3.5 peak sun-hours (90% of 3.9 peak sun-hours).

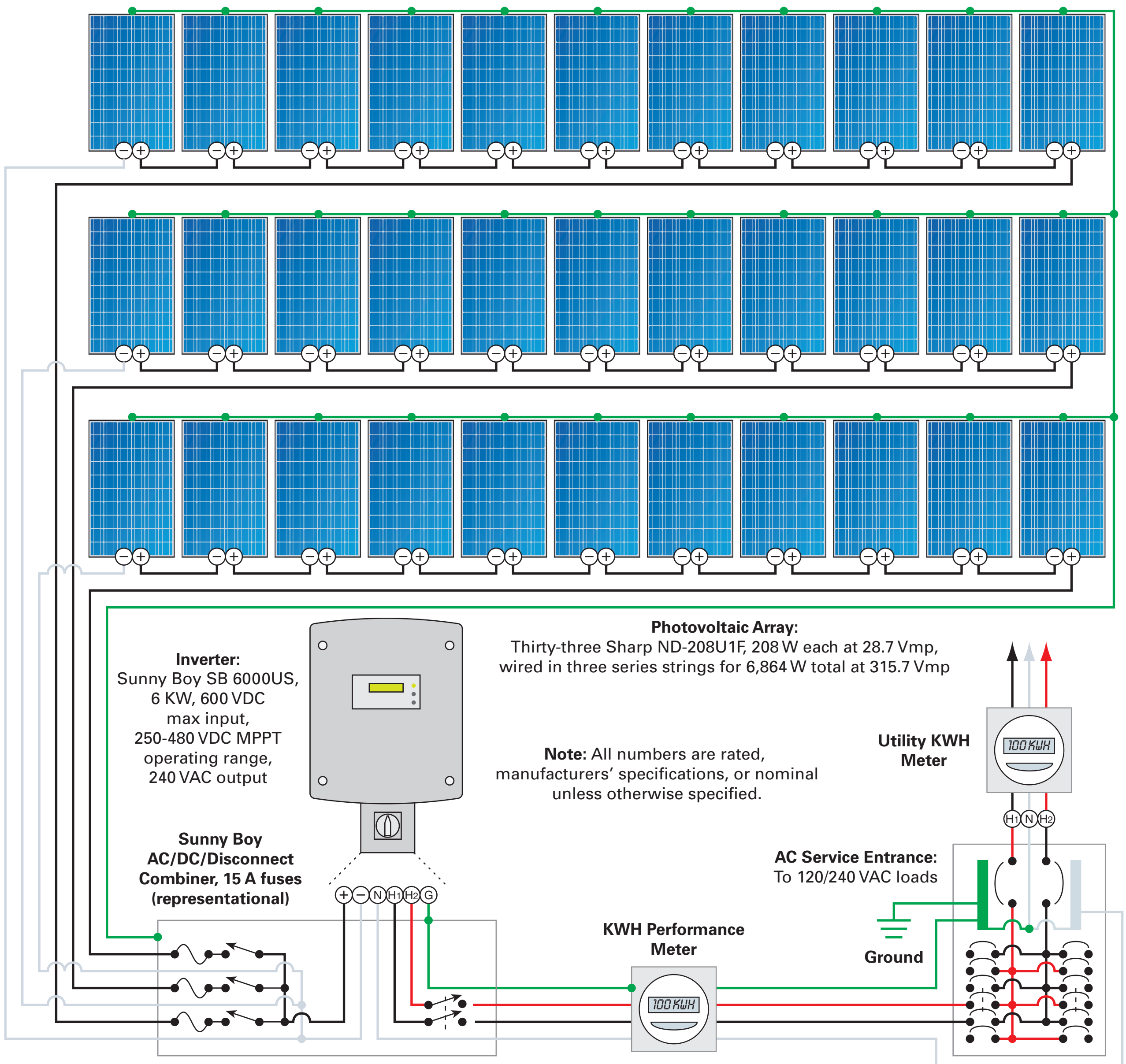
It could be argued that a 15% correction factor might be in order, allowing for temperature derating, soiling, and other factors. However, we felt 10% would be a reliable number, given Portland's moderate average daytime temperature (62°F), plenty of rain to keep modules clean, and an awning-mounted system with excellent backside air circulation that keeps module operating temperatures lower than if they were mounted parallel to the roof.

To calculate the size of the PV array we'd need, we divided the average daily KWH load by adjusted peak sun-hours to get the peak kilowatt rating of PV modules needed to reach net zero-energy. Although calculations showed that

For easier and speedier installation, the array was divided into three-module subarrays.

The Sunny Boy inverter, with the combined DC/AC disconnect, and a KWH production meter.

Mr. Sun Solar's Grid-Tie PV System



we'd need a 6.57 KW array, it's good to oversize slightly. As it happened, 33 Sharp 208 modules in landscape layout perfectly fit the awning area we planned for the PV array. This configuration gave us a DC-rated 6.86 KW and a 4% margin of error in our estimate to reach zero.

To verify the sizing, I ran another calculation based on the actual annual production of installed PV systems in the area. I had good data from several customers. One in particular had installed a 3 KW system three years prior. He found that he was getting an average of 1,214 KWH per year for each peak KW of PV on his roof. Using his real-world numbers, I multiplied 1,214 and 6.864 (the size of our PV array) to get 8,333 KWH for the year. Dividing 8,333 by 365 days, I got 22.8 KWH per day—almost exactly what we needed.

System Rebates

Item	Amount
Initial cost	$67,500
Incentives	
Oregon tax credit	-$27,000
Federal tax credit	-11,670
Energy Trust of Oregon rebate	-8,580
Total Incentives	-$47,250
Total Cost	$20,250

Configuring the System

The array is comprised of three, 11-module strings, feeding a single SMA America Sunny Boy 6,000 W inverter. The SB 6000US features a handy and time-saving extra—a built-in, four-pole disconnect, so both the AC and DC can be turned off with one switch. As required by Energy Trust of Oregon, we installed a Centron permanent KWH meter to keep an uninterrupted record of the system's AC output in the event that the inverter might have to be serviced.

Before installing the system, we hired an engineer to make sure the steel awning on the front of the building would support a half-ton of additional module and racking weight. Once we received the thumbs up, we got to work, mounting groups of three modules together on the ground, which allowed us to precisely set two parallel underside rails to match the modules' bolt-hole pattern. Because someone had recently stolen modules from a similar awning mount system on a nearby building, we riveted cover plates over the bolts as a theft deterrent.

Using a boom lift, we raised each three-module group and positioned it on the frame. Four assistants put up the whole PV array in a day. We had already installed the inverter, had an electrician do the AC wiring, and ran conduit while waiting for the engineering report. It just took one more day to complete the DC wire run and then the system was ready to go.

Throwing the Switch

On August 25, 2007, the day after we finished installing the system, we hosted a "Throwing the Switch" open house to celebrate. Representatives from Pacific Power came to install the net meter and brought along a photographer to cover the story for their company's newsletter. Our project was apparently big news, as it had established the first "truly" net zero-energy commercial facility in the company's six-state service district.

Even as a solar installer who has personally completed almost 2,000 solar projects, I still get a thrill when flipping the switch for the first time. Ironically, the big moment was delayed by a local power outage caused by a car accident that had damaged a transformer. But we didn't let an outage slow down the party. We quickly rigged a battery-based portable PV system to provide electricity for lighting and music, including the ever-so-appropriate Beatles' classic, "Here Comes the Sun." We roasted hot dogs and baked cookies in solar cookers.

Unfortunately, when we did finally flip the switch later that day after power had been restored, we discovered a

Tech Specs

Overview

System type: Batteryless, grid-tie solar-electric

Location: Portland, Oregon

Solar resource: 3.9 average daily peak sun-hours

Average monthly production: 694 AC KWH

Utility electricity offset annually: 100%

Components

Modules: 33, Sharp ND-208U1F, 208 W STC, 28.7 Vmp

Array: Three, 11-module series strings, 2,288 W STC each, 6.86 KW total, 315.7 Vmp

Array installation: Custom 1.5 in. aluminum square tube mounts installed on south-facing awning, 15-degree tilt

Inverter: SMA SB 6000US, with integrated 15 A fused combiner and AC/DC disconnect, 6 KW rated output, 600 VDC maximum input, 250–480 VDC MPPT operating range, 240 VAC output

System performance metering: Centron Itron KWH meter

Paying for the System

Professionally installed PV systems in our area run about $10 per peak watt. For the system I sized for our net zero-energy building, I was looking at an investment of almost $68,000. My first thought was, "Yikes! Where am I going to get that kind of money?"

I considered the possibility of finding a third-party investor, who would buy the system, take the tax credits, utility incentives, and depreciation, and then lease the equipment to our business. In turn, we'd pay rent on the system for a cost roughly equal to the projected energy savings. However, since this option is generally used with larger systems, I had trouble finding a third party interested in our relatively small project. I did eventually have one taker, but in the end, the buy-out provision of the lease asked for "fair market value," which could have been $50,000 or more with appreciation—more than I was willing to pay. I didn't want to end up paying for the system twice.

Instead, I found unsecured private financing at 7%. A low-interest loan through the state of Oregon's Solar Energy Loan Program would have come with a slightly more competitive rate, but the terms required that I take out a second mortgage on the building—which didn't appeal to me. Though I was not wild about taking on such a large loan, the numbers were less daunting once I factored in all the tax credits and incentives: an $8,580 rebate from the Energy Trust of Oregon; a $11,670 federal tax refund (30% of the system's cost, less the Energy Trust of Oregon incentive); and a $27,000 state tax credit taken over five years.

In the first six months of the loan, I recovered about half of the loan amount. By the time all the credits come in, I will have covered nearly 80%. With all the incentives, the actual tax reduction from depreciation, and the value at current electric rates of the energy saved by the system, I estimate full payback in seven years. It was that easy. With just a few pushes of the pencil, I went from "Yikes!" to "Done deal!"

Phantom Protection

Any net zero-energy home or business must zealously guard against phantom loads—energy that is gobbled up even when equipment is turned "off." To slay these energy wasters, we plug our photocopy/fax machine and every computer into power strips that are switched off every night. All devices with wall cubes are also plugged into power strips. We even went so far as to do away with a doorbell, and selected a microwave that does not have an LED clock. The building is as phantom-proof as we know how to make it.

An exception—over coffee—was almost made when office java drinkers organized and requested an automatic coffee maker. Brewing coffee and keeping it hot all day was not something I was excited about, especially since I'm not a coffee drinker. But we compromised—I allowed the coffee maker, but only on the grounds that it is turned off immediately after coffee is brewed, and the coffee is transferred into an insulated dispenser that keeps it warm all day.

technical problem—the SMA inverter kept blowing fuses. We got the company's technical support on the phone and worked through the possible scenarios. Based on their suggestion, we decided to rewire and bring the three individual strings into the inverter rather than combining them at the array.

A week later, with the rewiring complete, we gave it another go on a gorgeous, sunny day. The system cranked out 31 AC KWH on that first day. And the best part: Our new Pacific Power bidirectional meter read zero when it was first installed, and the first number recorded was -1. There was nothing like watching the meter spin backward, knowing that we were well on our way to net zero-energy use.

Access

John Patterson (jp@mrsunsolar.com) is president of Mr. Sun Solar and inventor of the Sol-Reliant solar water heating system. Over the past 28 years, his company has installed more than 1,900 solar energy systems, including solar hot water, solar pool heating, and photovoltaic systems.

Suzanne Olsen (suzolsen@integra.net) is a writer and photographer specializing in renewable energy and the environment.

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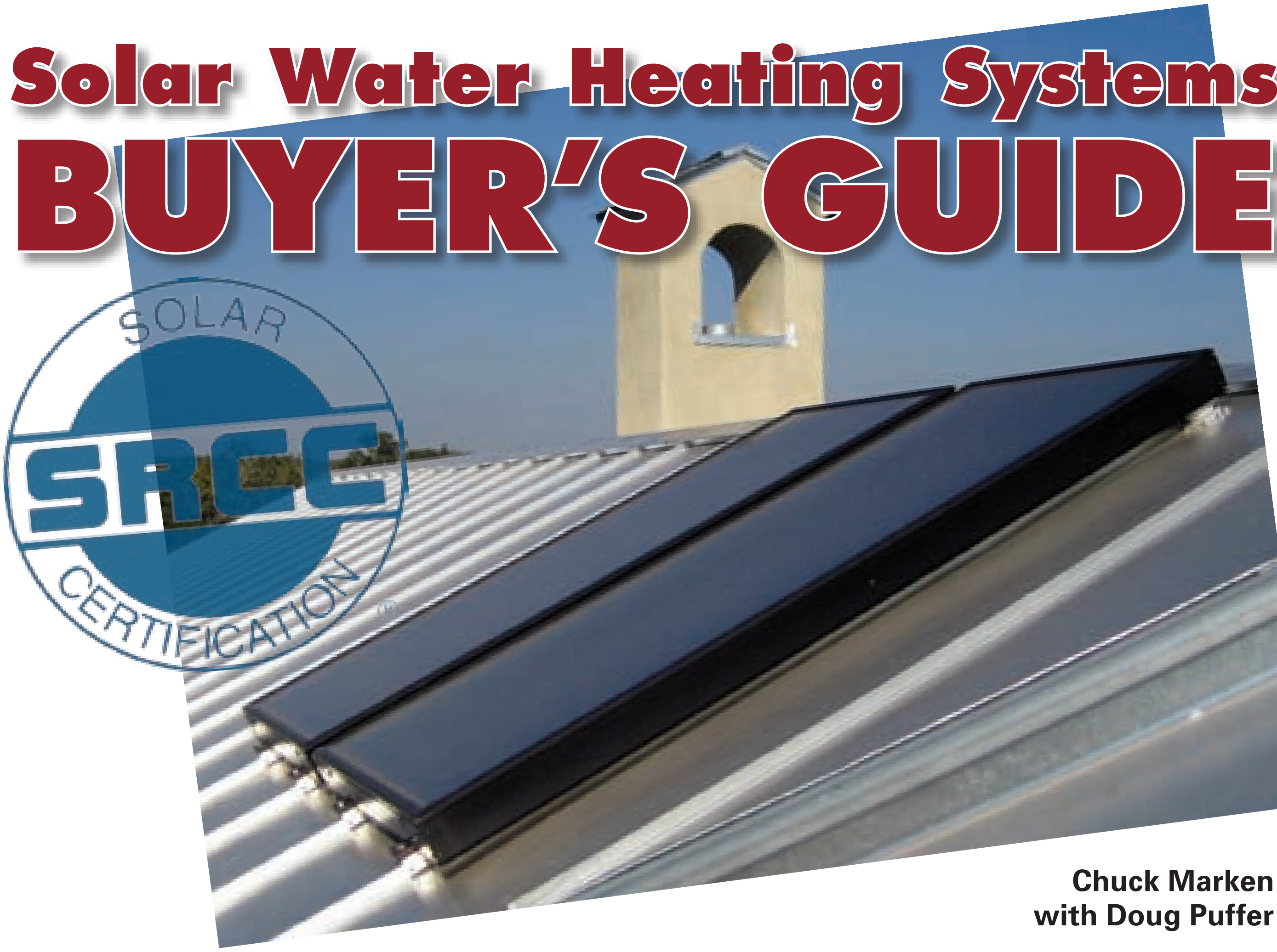
Solar Water Heating Systems BUYER'S GUIDE



Courtesy www.synergysolar.com

Chuck Marken
with Doug Puffer

For most of us, performance matters, whether we're shopping for a new car or choosing a solar water heating system. For cars, their estimated fuel economy—miles per gallon—can influence which model offers the best value. Although these EPA testing numbers aren't necessarily "real-world," they can give us a guideline to go by. Solar hot water (SHW) system performance is not much different. In this case, systems are evaluated by an independent testing agency—then certified by the Solar Rating and Certification Corp. (SRCC). And their ratings are the next best thing to real-world performance.

Considering Your Choices

Our list of solar water heating systems is condensed from the SRCC's Operating Guidelines 300 (OG-300) catalog, since we didn't have room to list the more than 500 SRCC certified systems. Instead, we tried to include every SHW system manufacturer, but pared the list to 130 individual systems, which were selected by two criteria: typical residential tank size (40 to 120 gallons) and typical collector sizing (1 square foot of collector area to every 1 to 2 gallons of water stored).

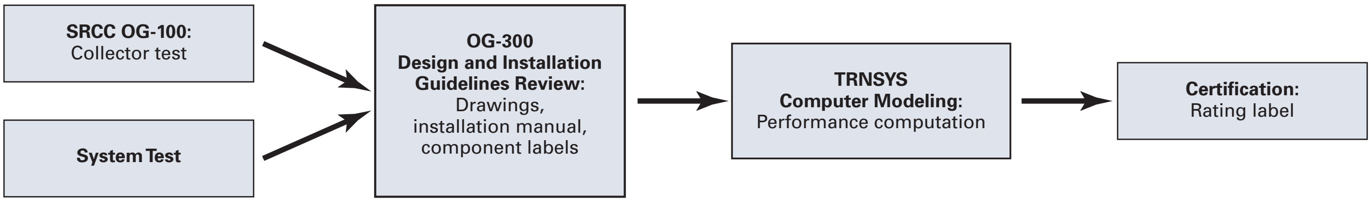
Only seven or eight efficient systems per manufacturer were included in each climate category. To compare apples to apples, all the systems listed in our table are assumed to have electric backup heating. The included data is current as of March 1, 2008—for updates, visit the SRCC Web site. If you want a more detailed look at all the systems, but don't want to wade through the SRCC's 309-page catalog, check out our complete spreadsheet of OG-300 systems at www.homepower.com.

System Certification

In *HP123*, we featured a guide to selecting a solar hot water collector—the "engine" of a SHW system that gathers the energy. While the collector is the *most* important component in a solar water heating system, it is only one component of several that work together. Once the energy is gathered, it needs to be stored for on-demand use. The other components of an SHW system facilitate the storage and distribution of the solar-heated water, and greatly influence how much hot water is available.

While choosing a collector is important, knowing how the entire system will perform is crucial. And getting an idea of how one system stacks up against another will help you maximize your investment. The SRCC OG-300 standards provide a relative performance comparison of various solar water heating systems. Certification requires testing the collectors under the OG-100 standard and testing the entire system. (Note that some collectors are integrated with the storage tank, such as integral collector and storage and thermosyphon systems, and are listed only in the OG-300 catalog.) Before a system can be certified, a design and installation review, and a performance computation must be completed.

SRCC's OG-300 Certification Process



Collectors and systems are tested under standard laboratory conditions that are certain to be different from those at your home. Testing is a combination of durability and performance, with the test procedures for performance specified by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE Standard 93, "Methods of Testing to Determine the Thermal Performance of Solar Collectors").

What's Your Climate?

Before you select a system, you'll need to classify your climate area as either "mild" or "harsh." For the purposes of the table (see page 96), we split the list according to each system's freeze tolerance—or lack of it—and set the dividing line at 10°F.

However, since water freezes under different conditions of temperature, pipe size, liquid flow, insulation, and time, there are no hard-and-fast divisions—it's very difficult to give a rule that will work everywhere under all conditions.

In "mild" climates, where freezing conditions are uncommon, potable water can be used directly in the collector loop. In SRCC lingo, this is a "Type I fluid system." These mild-climate systems have no heat exchangers, and are usually simpler and less expensive, with few components. However, because of their limited freeze tolerance, these systems, which include integrated collector storage (ICS) systems, direct forced-circulation systems, and open-loop thermosyphon units, are generally limited to installation in Hawaii and the southernmost part of the United States—states that border Mexico or the Gulf of Mexico.

The rest of the United States is classified as falling in the "harsh" climate, since the probability of freezing is far greater. These areas are best served with true freeze-tolerant systems, which have heat exchangers, and are either drainback systems that use potable water (Type I fluid system) or nontoxic antifreeze systems (Type II fluid system). The SRCC catalog refers to these systems as "indirect forced-circulation systems."

Solar Hot Water System-Types Compared

System Type	Climate & Description	Advantages	Disadvantages	Installation
Integral Collector Storage (ICS)	Passive: Open loop for mild climates	Simplicity; lowest cost	Poor freeze protection; poor tank insulation	Heavy units; easy to install; can have cosmetic-appearance issues
Thermosyphon	Passive: Open loop for mild climates; closed loop can be used in harsh climates	Simple open loop; tank is insulated	Open loop has poor freeze protection; closed loop needs a heat exchanger; potable water lines to collector subject to freezing	Very heavy systems; easy to install; can have cosmetic-appearance issues
Direct Pump: Direct circulation	Open loop for mild climates only	Simple active system; can be PV powered	Poor freeze protection; freeze valves can give false security	Easy installation; needs electrical source
Drainback: Closed loop, forced circulation	Closed loop for all climates	Simple system when compared to antifreeze systems; limited overheating	Needs a high-head pump and heat exchanger; harder to power with PV	Slope of collectors and piping is critical
Closed-Loop Antifreeze: Forced circulation	Closed loop for all climates	Best freeze protection; easily PV powered	Most complex; can have overheating problems; needs a heat exchanger	Most difficult installation

MILD CLIMATE SYSTEMS

Integral Collector Storage

Passive ICS systems (batch water heaters) are the simplest solar water heater. Cold water flows under normal water pressure to the bottom of the tank, and hot water is taken off the top. Whenever there's a call for hot water, hot water moves from the top of the solar batch heater as cold water is pushed into the bottom. Most of the ICS units produced in the United States today are progressive-tube-type heaters as opposed to single-tank units. Although the storage tank(s) of ICS systems are freeze-tolerant in normal operation, the weak point in the system is the potable water pipes running to and from the units. These systems are climate limited and are included in the mild-climate listings. (For more information on ICS systems, see *HP93* & *HP108*.)

Thermosyphon

These systems position an insulated solar storage tank higher than the collector, relying on the principle of heat rising to move water through the system. These open-loop systems are more climate-limited than ICS systems because the small riser tubes in the collector are vulnerable to freezing. However, thermosyphon systems can be configured in a closed-loop design, using antifreeze in the collector and a heat exchanger and potable water in the tank. Because closed-loop thermosyphon systems have potable domestic water lines to and from the collector, their Achilles' heel, they are vulnerable to freezing.

The advantage of this system over the batch heater is that solar heat is stored in a well-insulated tank, so hot water can be used any time with lesser penalty of overnight losses. The SRCC lists open-loop systems as "direct thermosyphon" and closed-loops as "indirect thermosyphon." (A direct thermosyphon system is described in detail in *HP97*.)

Direct Pump

Used in tropical settings where freezing never occurs, this is the simplest of the active systems, using a pump and a standard tank with electrical elements teamed with a solar thermal collector. A direct-pump system is also known as a "direct-forced circulation" system by SRCC classifications. In this open-loop system, the collector-loop fluid is potable water. As with ICS and open-loop thermosyphon systems, potable water must run outside to the collector, and the associated plumbing is vulnerable to freezing. A weaker freeze link is the smaller riser tubes connected to the header tubes. They are subject to freezing before the insulated potable water lines. Direct-pump systems can easily be married to a PV module that will power a DC pump. Direct forced-circulation systems are very popular in places like Hawaii, which has mild temperatures and plenty of sunshine.

Freeze-Protection Gizmos—Caveat Emptor

In an attempt to have their systems reclassified to gain more sales, some manufacturers have incorporated freeze-protection schemes into their "mild climate" systems. The bottom line? Buyer beware if you're considering installing one of these systems in your "harsh" climate. Only two designs—drainback and antifreeze systems—offer reliable freeze protection in these areas. Here are some freeze-protection devices that have caused collectors to freeze in the past —and consequently have required expensive repairs or replacement.

Direct pump with recirculation. Some differential controls for turning pumps on and off also have a "freeze-protection feature" that can be set to recirculate water from the storage tank to the collector. The logic is that the warmed, stored water can be routed to the collector to prevent it from freezing. But this method has ruined collectors when unusually bad winter storms move in and power outages occur. Without electricity to power the control and pump, water can stagnate in the collector, and a hard freeze can burst the collector riser tubes.

Freeze valves (a.k.a. dribble valves). For freeze protection, some direct-pump, ICS, and thermosyphon systems use a freeze valve, a passive valve that is set to open at a low temperature (either 35°F or 45°F). When the valve opens, water from the municipal or well system enters the collector, and the near-freezing water in the collector dribbles from the valve onto the roof or the ground. Although this strategy is perhaps more reliable than recirculation systems, it is far from fail-safe. Hard (mineral-laden) water can eventually clog the valve, and poof!—the supposed freeze protection is gone.

Draindown valves, which were incorporated into direct-pump systems all over the United States, have been one of the worst hiccups in solar-thermal history. At a preset, low temperature, a controller activated the valves to divert water in the collectors to drain outside. However, like freeze valves, draindown valves were prone to failure due to corrosion, hard-water deposits, and clogging. Typically, the first winter freeze ruined the collector—when the valve failed, the collectors remained full of water and froze.

HARSH CLIMATE SYSTEMS

Drainback

These indirect forced-circulation systems are reliable, freeze tolerant, and fairly easy to install. The closed-loop drainback system requires perhaps the least amount of maintenance of any indirect, active system. The heat-transfer fluid is distilled water, which seldom has to be changed. When the system is not pumping, the solar collector is empty with the water having drained to the reservoir tank, usually located just above the solar storage tank. Higher-capacity reservoir tanks are typically required in large systems. The system relies on the collectors and piping being drained when freezing conditions are possible. Both are sloped toward the drainback tank so that when the pump turns off, the water in the collector loop passively drains back into the tank.

Since the pump must have enough power to push water from the drainback-tank fluid level to the top of the collectors—a distance that can be 20 or 30 feet—most installations require a high-head pump. Because of the head requirements and the limited choices in DC pumps, drainback systems are tougher to adapt to direct PV power. (Drainback systems are featured in *HP86* & *HP97*.)

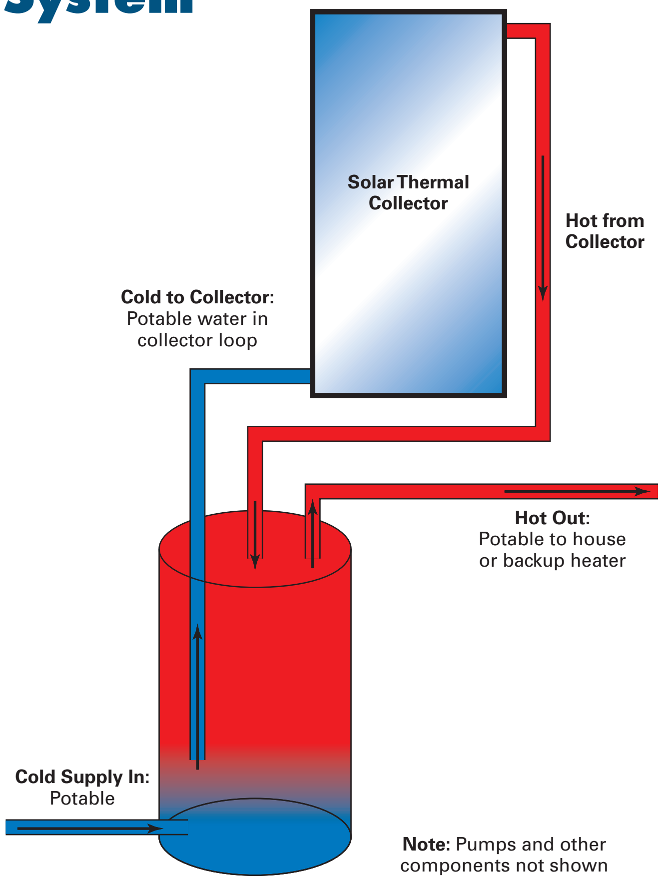
Antifreeze

This is the most complex indirect forced-circulation, closed-loop system—and therefore the most difficult to install. It also is the system with the best freeze protection, and as such, is popular in northern climates.

In this active, closed-loop system, incoming potable water is routed to the solar storage tank, but never into the collectors. A water–antifreeze mixture circulates from the collectors through a heat exchanger and then is pumped back through the collectors.

Antifreeze systems can overheat in the summer if there is too much collector surface area relative to tank storage volume. Overheating can be combated by using the "vacation mode" of newer differential controls, which will allow fluid to circulate through the system at night, cooling the fluid. PV-powered systems can incorporate a bypass valve around the check valve, which will allow the system to reverse thermosyphon at night to cool the antifreeze. (See Bob Inouye's article in *HP123* for details of a bypass valve. Antifreeze systems were covered in depth in *HP85* & *HP95*.) For a good overview of the five systems mentioned here, see "Solar Hot Water: Simplified" in *HP107*.

Basic Open-Loop System



Basic Closed-Loop System

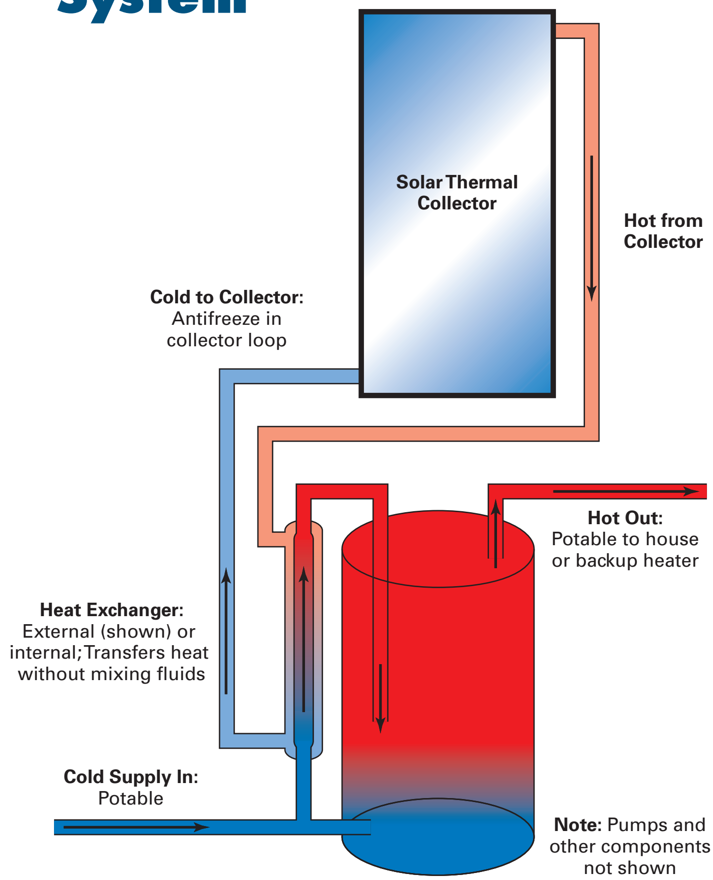


TABLE SPECS

Freeze-Tolerant Temperature—The temperature at which manufacturers estimate some part of the system is vulnerable to freezing. The SRCC says that "unless a system is installed in a nonfreezing climate, every system must have an automatic mechanism to at least partially protect it from freezing (i.e., automatic draining, antifreeze fluids, or thermal mass)."

Collector Size—The collector size for a given system is determined by the storage-tank volume and the amount of sunlight available at the installation site. The size of the collector is important: It must be large enough to do the job but not so big that it is a waste of money or causes overheating.

Storage Tank Size—System sizing is normally based on a one-day recovery time, which means that the storage tank should be large enough to satisfy the demands of a household for one day, at a minimum.

Annual KWH Saved—The SRCC catalog boils performance data down to savings estimates—given in annual estimated KWH—in several cities. We chose San Diego; Richmond, Virginia; and Seattle to represent sunny, partly cloudy, and cloudy climate conditions, respectively. The SRCC has modeled

MILD CLIMATE SYSTEMS

Manufacturer	Freeze Tolerant Temp. (°F)	Collector Size (Sq. Ft.)	Storage Tank Size (Gal.)	Annual KWH Saved		
				San Diego, CA	Richmond, VA	Seattle, WA
ACR Solar Intl.	30°	40.1	50	2,600	2,100	1,700
Energy Laboratories Inc.	22°	30.8	68	2,500	2,100	1,600
Heliodyne Inc.	27°	53.5	80	3,600	3,200	2,600
	27°	64.5	120	3,700	3,300	2,700
	27°	64.5	80	3,600	2,900	2,400
	27°	80.3	120	3,500	3,400	2,900
	27°	80.3	120	3,800	3,500	2,900
	27°	96.7	120	3,700	3,100	2,500
	27°	120.4	120	3,500	3,400	3,000
Integrated Solar LLC	20°	25.0	40	1,500	1,200	1,000
	20°	33.2	50	1,900	1,600	1,300
Rheem Water Heaters	19°	42.7	77	2,200	1,600	900
Solahart Industries	19°	85.4	113	3,300	2,500	1,600
	19°	85.4	113	3,300	2,500	1,600
	19°	64.0	77	3,000	2,600	2,100
	19°	85.4	113	3,200	2,800	2,200
	19°	85.4	113	3,200	2,800	2,300
	41°	64.0	90	3,500	2,700	2,200
	41°	64.0	114	3,600	2,700	2,200
Solene	20°	64.0	120	3,500	3,100	2,500
	20°	80.1	120	3,700	3,600	3,000
	20°	60.6	80	3,800	3,500	2,800
	20°	80.1	120	3,900	3,900	3,100
	20°	77.7	120	3,700	3,500	2,900
	20°	63.6	120	3,800	3,600	2,800
	20°	77.7	120	3,800	3,800	3,000
SunEarth Inc.	20°	39.7	64	2,400	2,000	1,700
	20°	49.8	84	2,600	2,200	1,800
	41°	40.9	80	3,000	2,500	2,000
	41°	40.9	80	3,100	2,600	2,000
	15°	73.9	116	3,000	2,600	2,100
	15°	81.7	116	3,300	2,800	2,300
	15°	65.7	80	3,000	2,500	2,000
Thermal Conversion Technology Inc.	10°	32.1	40	2,200	1,900	1,500
	10°	32.1	50	2,300	1,900	1,500

the systems data for many other cities in the United States and also provides listings on systems with gas backup, which are not included in our condensed table.

System Type—The catalog lists the systems by four types: integral collector storage (ICS, a.k.a. batch water heater); thermosyphon systems (open and closed loop); forced-circulation systems (direct pump, drainback, and antifreeze); and self-pumping systems. (Note: There are no self-pumping systems currently certified.)

Controller—Found only in forced-circulation (active) systems, controllers energize the system pump at the appropriate time. There are differential controllers, systems without controllers, and systems that use a PV module to automatically turn on the pump when the sun shines.

Fluid Used—Only two types of fluids, water (Type I fluid) and nontoxic propylene glycol antifreeze (Type II) mixed with water, are used in modern SHW systems.

Heat Exchanger—Transfers the energy collected by the collector-loop fluid to the domestic water used in the home. The type and size of heat exchanger can influence the system efficiency significantly. (For more info, see *HP92*.)

System Name	System Model	System Type	Collector Model	Aux. Tank Size (Gal.)	Fluid	Controller	Supply-Side Heat Exchanger
Skyline System 3	200132C502TE	Direct Forced Circulation	ACR Solar 20-01	50	Water	PV Panel Controller	None
Roof Integrated Thermosyphon	RITH 72 E	Direct Thermosyphon	Energy Lab. RITH-72	50	Water	None	None
Helio-Flo	HF 23366 G 80 AC S E	Direct Forced Circulation	Heliodyne - 336 000	None	Water	Differential Controller	None
	HF 2408 G 120 AC S E		Heliodyne - 408 000				
	HF 2408 G 80 AC S E		Heliodyne - 408 000				
	HF 2410 G 120 AC D E		Heliodyne - 410 000	50			
	HF 2410 G 120 AC S E		Heliodyne - 410 000	None			
	HF 3408 G 120 AC S E		Heliodyne - 408 000				
	HF 3410 G 120 AC D E		Heliodyne - 410 000	50			
CopperSun	CS340SV-E	Direct Integral Collector Storage	Sun Systems - CS 340	50	Water	None	None
	CS450-E		Sun Systems - CS 450	50			
Rheem Solaraide	RS80-42BP	Indirect Thermosyphon	Rheem - RS21-BP	None	Glycol	None	Mantle Heat Exchanger with a Single Wall
Solahart	444BCXII	Indirect Thermosyphon	Solahart - KF	None	Glycol	None	Mantle Heat Exchanger with a Single Wall
	444KF & 444KF Free Heat						
	ASE 303BCXII						
	ASE 444BCXII						
	ASE 444KF & ASE 444KF Free Heat						
Streamline Electric	340SL-3Bt	Direct Forced Circulation	Solahart - Bt		Water	Differential Controller	None
	430SL-3Bt						
Solene/Chromagen DC Open Loop	SLCR64DC-80	Direct Forced Circulation	Solene - SLCR-32	None	Water	Differential Controller	None
	SLCR80DC-120		Solene - SLCR-40				
Solene/Chromagen PV Open Loop	SLCR60PV-80		Solene - SLCR-30			PV Panel Controller	
	SLCR80PV-120		Solene - SLCR-40				
Solene/Corona DC Open Loop	SLCO80DC-120		Solene - SLCO-40			Differential Controller	
Solene/Corona PV Open Loop	SLCO64PV-120		Solene - SLCO-32			PV Panel Controller	
	SLCO80PV-120		Solene - SLCO-40				
CopperHeart	CP-60P	Direct Integral Collector Storage	SunEarth - CP-30	50	Water	None	None
	CP-80P		SunEarth - CP-40	50			
SunSaver	NF40P-80S	Direct Forced Circulation	SunEarth - EP-40	None		Differential Controller	
	NF40P-80T		SunEarth - EP-40				
SunSiphon	EPGX116-63-2	Indirect Thermosyphon	SunEarth - EP-24	50	Glycol	None	Mantle Heat Exchanger with a Single Wall
	EPGX116-80-2		SunEarth - EP-40	50			
	EPGX80-64-2		SunEarth - EP-32	50			
ProgressivTube	PT-40-CN	Direct Integral Collector Storage	TCT - PT-40-CN	50	Water	None	None
	PT-50-CN		TCT - PT-50-CN	50			

HARSH CLIMATE SYSTEMS

Manufacturer	Freeze Tolerant Temp. (°F)	Collector Size (Sq. Ft.)	Storage Tank Size (Gal.)	Annual KWH Saved		
				San Diego, CA	Richmond, VA	Seattle, WA
ACR Solar Intl.	-54°	40.1	80	2,300	1,900	1,600
	-54°	40.1	80	2,200	1,800	1,500
Alternate Energy Technologies	-20°	98.0	120	3,200	3,000	2,400
	-20°	63.8	120	3,300	3,100	2,500
	-20°	65.3	120	3,300	3,100	2,500
	-20°	79.6	120	3,400	3,300	2,700
	-20°	63.8	80	3,300	3,000	2,400
	-20°	65.3	80	3,300	3,000	2,400
	-20°	79.6	80	3,400	3,200	2,600
BFT Ltd.	-50°	33.1	65	1,500	1,300	1,100
	-50°	66.2	80	2,400	2,000	1,700
Bobcat & Sun Inc.	-60°	64.5	80	2,800	2,500	2,000
	-60°	64.5	80	3,000	2,700	2,200
	-60°	64.6	80	2,900	2,600	2,100
	-60°	65.7	80	2,900	2,600	2,100
Butler Sun Solutions	-54°	40.9	80	2,400	2,000	1,600
	-54°	40.9	80	2,500	2,000	1,500
	-54°	40.9	80	2,500	2,000	1,500
Enerworks Inc.	-50°	61.9	80	3,000	2,700	2,200
	-50°	92.8	120	2,700	2,500	2,200
Fafco Inc.	-20°	47.4	50	1,800	1,500	1,300
	-20°	47.4	80	1,900	1,600	1,300
	-20°	94.9	50	2,200	1,800	1,500
	-20°	94.9	80	2,300	2,000	1,600
Heat Transfer Products	-60°	43.6	80	NA	NA	NA
Heliodyne Inc.	-60°	53.5	80	3,200	2,800	2,200
	-60°	64.5	120	3,300	3,000	2,300
	-60°	80.3	120	3,500	3,200	2,600
	-60°	53.5	80	3,400	2,800	2,200
	-60°	80.3	120	3,600	3,200	2,600
	-60°	80.3	120	3,600	3,200	2,500
	-60°	96.7	120	3,700	3,400	2,700
Integrated Solar LLC	-60°	79.8	120	3,000	2,500	1,900
	-60°	39.9	65	2,200	1,800	1,400
	-60°	39.9	80	2,700	2,300	1,800
Morley Manufacturing	-60°	39.9	60	2,500	2,000	1,600
	-60°	40.1	60	2,500	2,000	1,600
	-60°	40.9	60	2,500	2,000	1,600
Mr. Sun Solar	-50°	39.8	80	2,900	2,500	2,000
	-50°	55.7	80	3,400	3,000	2,400

System Name	System Model	System Type	Collector Model	Aux. Tank Size (Gal.)	Fluid	Controller	Supply-Side Heat Exchanger
Skyline System 5	200152C80EX	Direct Forced Circulation	ACR Solar 20-01	None	Glycol	PV Panel Controller	Tank Wraparound Heat Exchanger with Double Wall and Positive Leak Detection
	200152C80EX2TE		ACR Solar 20-01	50			
EagleSun	DB-120-96	Indirect Forced Circulation - Drainback	MSC-32	None	Water	Differential Controller	Tank Wraparound Heat Exchanger with a Single Wall
EagleSun DX	DX-120-64		AE-32				Immersed Coil Heat Exchanger with a Single Wall
	DX-120-64		MSC-32				
	DX-120-80		AE-40				
	DX-80-64		AE-32				
	DX-80-64		MSC-32				
	DX-80-80		AE-40				
Solar Patriot	SP20-1-65G-PV-E	Indirect Forced Circulation - Antifreeze	BFT - SP-20	50	Glycol	PV Panel Controller	Immersed Coil Heat Exchanger with a Double Wall
	SP20-2-80G-PV-E		BFT - SP-20	50			
Sun-Pak	SP64CHE	Indirect Forced Circulation - Antifreeze	Heliodyne - 408 000	None	Glycol	Differential Controller	Tank Wraparound Heat Exchanger with Double Wall and Positive Leak Detection
	SP64CHE-1		Heliodyne - 408 000	None			
	SP64PHE-1		Radco - 408P-HP	None			
	SP64PHE-1		SunEarth - EP-32	None			
Solar Butler	BSS-PV1-80E2b	Indirect Forced Circulation - Antifreeze	SunEarth - SC-40	50	Glycol	PV Panel Controller	Immersed Coil Heat Exchanger with a Double Wall and Positive Leak Detection
	BSS-PV1-80Ea		SunEarth - SC-40	None			
	BSS-S1-80Ea		SunEarth - SC-40			Differential Controller	
Solar Water Heating Appliance	EWRA2-E80	Indirect Forced Circulation - Antifreeze	Enerworks - COL-4x8-TL-SG1-SD10US	50	Glycol	Differential Controller	Plate Heat Exchanger with a Single Wall
	EWRA3-E120		Enerworks - COL-4x8-TL-SG1-SD10US	50			
Polymer Drainback	VDB-48U-50E-50S	Indirect Forced Circulation - Drainback	Fafco - Revolution	50	Water	Differential Controller	Plate Heat Exchanger with a Single Wall
	VDB-48U-50E-80S			50			
	VDB-48UX2-50E-50S			50			
	VDB-48UX2-50E-80S			50			
SuperStor Contender Solar	SSC-80SE	Indirect Forced Circulation - Antifreeze	Apricus - AP-30	None	Glycol	Differential Controller	Immersed Coil Heat Exchanger with a Single Wall
Heliopak	16 DWCL HP 2 3366 G 80 ACS	Indirect Forced Circulation - Antifreeze	Heliodyne - 336 000	None	Glycol	Differential Controller	Shell-and-Tube Heat Exchanger with a Double Wall and Positive Leak Detection
	16 DWCL HP 2 408 G 120 ACS		Heliodyne - 408 000				
	16 DWCL HP 2 410 G 120 ACS		Heliodyne - 410 000				
Helio-Pak Helix SS PV	HP HX SS 2 3366 G PV 80 EE S		Heliodyne - 336 000			PV Panel Controller	
	HP HX SS 2 410 G PV 120 SE S		Heliodyne - 410 000				
	HP HX SS 3 3366 G PV 120 SE S		Heliodyne - 336 000				
	HP HX SS 3 408 G PV 120 SE S		Heliodyne - 408 000				
RadCo Drainback Heat Exchanger	R-DBHX-8-120S-80P	Indirect Forced Circulation - Drainback	Radco - 410P-HP	None	Water	Differential Controller	Immersed Coil Heat Exchanger with a Single Wall
	R-DBHX-8-65S-40P		Radco - 410P-HP				
	R-DBHX-8-80S-40C		Radco - 410C-HP				
High Sierra Drainback	HS60B/40	Indirect Forced Circulation - Drainback	Radco - 410P-HP	50	Water	Differential Controller	Shell-and-Tube Heat Exchanger with a Single Wall
	HS60B/40		Heliodyne - 410 000	50			
	HS60B/40		SunEarth - EC-40	50			
Sol-Reliant	SR 40/80 E PVDB	Indirect Forced Circulation - Antifreeze	AE-40	50	Glycol	PV Panel Controller	Tank Wraparound Heat Exchanger with a Double Wall and Positive Leak Detection
	SR 56/80 E PVDB		AE-56	50			

HARSH CLIMATE SYSTEMS

Manufacturer	Freeze Tolerant Temp. (°F)	Collector Size (Sq. Ft.)	Storage Tank Size (Gal.)	Annual KWH Saved		
				San Diego, CA	Richmond, VA	Seattle, WA
Schuco USA L.P.	-40°	58.1	80	3,000	2,700	2,200
	-40°	87.1	120	3,300	3,100	2,500
	-40°	49.7	80	2,900	2,500	2,100
	-40°	74.6	120	3,300	3,000	2,400
Solar Energy Inc.	-20°	115.7	120	3,400	3,100	2,500
	-20°	119.4	120	3,400	3,100	2,500
	-20°	95.7	120	3,300	3,000	2,300
	-20°	98.5	120	3,300	3,000	2,300
	-20°	65.6	80	3,100	2,700	2,200
	-20°	77.1	80	3,200	2,900	2,300
	-20°	79.6	80	3,200	2,900	2,300
Solarhot	-10°	64.0	80	3,400	3,200	2,600
	-10°	64.5	80	3,400	3,200	2,600
Solene	-10°	60.6	80	3,200	2,900	2,300
	-10°	64.0	80	3,300	2,900	2,400
	-10°	63.6	80	3,200	2,800	2,300
	-10°	77.7	80	3,400	3,000	2,500
	-10°	77.7	80	3,200	2,900	2,300
	-10°	63.6	80	3,200	2,800	2,300
	-10°	77.7	80	3,400	3,000	2,500
Stitt Energy Systems Inc.	-40°	79.6	120	3,100	2,600	2,100
	-40°	39.8	80	2,300	1,900	1,600
SunEarth Inc.	-50°	65.7	80	3,200	2,900	2,400
	-60°	65.7	80	3,500	3,200	2,600
	-60°	65.7	80	3,500	3,000	2,400
	-60°	65.7	80	3,400	3,100	2,500
	-60°	81.7	120	3,600	3,400	2,800
	-60°	81.7	120	3,400	3,300	2,700
	-60°	81.7	120	3,700	3,300	2,600
	-60°	81.7	120	3,600	3,300	2,700
Synergy Solar	-50°	39.6	80	2,700	2,200	1,800
	-50°	53.4	80	3,100	2,600	2,100
	-50°	53.4	80	3,000	2,600	2,100
	-50°	59.4	80	3,000	2,700	2,200
	-50°	53.4	80	2,700	2,300	1,900
Thermomax Industries Ltd	-60°	65.9	80	3,200	2,900	2,300
	-60°	82.2	120	3,400	3,100	2,500
	-60°	98.6	120	3,500	3,400	2,700
	-50°	92.1	120	3,400	3,100	2,500
	-50°	92.1	80	3,400	3,100	2,500
	-50°	107.4	120	3,500	3,300	2,600
Trendsetter Industries	-20°	81.7	120	2,800	2,500	2,100

System Name	System Model	System Type	Collector Model	Aux. Tank Size (Gal.)	Fluid	Controller	Supply-Side Heat Exchanger
Premium Package	Premium II-80E	Indirect Forced Circulation - Antifreeze	Schuco - V, H, LA	None	Glycol	Differential Controller	Tank Wraparound Heat Exchanger with a Double Wall and Positive Leak Detection
	Premium III-120E		Schuco - V, H, LA				
Slimline Package	Slimline II-80E		Schuco - V, LA				
	Slimline III-120E		Schuco - V, LA				
Duro-Drainback Solar Water Heating System	D2B-12009120	Indirect Forced Circulation - Drainback	Solar Energy - SE-40	None	Water	Differential Controller	Shell-and-Tube Heat Exchanger
	D2B-12009120		Alternate Energy Tech. - AE-40				
	D2B-12009-96		Alternate Energy Tech. - AE-32				
	D2B-12009-96		SunEarth - EP-32				
	D2B-8009-63		Solar Energy - SE-21				Tank Wraparound Heat Exchanger
	D2B-8009-80		Solar Energy - SE-40				
	D2B-8009-80		Alternate Energy Tech. - AE-40				
Solvelox DB	S-SV-DB100	Indirect Forced Circulation - Drainback	Solene - SLCR-32	None	Water	Differential Controller	Plate Heat Exchanger with a Single Wall
	S-SV-DB100		Heliodyne - 408 000				
Solene/Chromagen DC Closed Loop	SLCR60DC-80HE	Indirect Forced Circulation - Antifreeze	Solene - SLCR-30	None	Glycol	Differential Controller	Tank Wraparound Heat Exchanger with a Double Wall and Positive Leak Detection
	SLCR64DC-80HE		Solene - SLCR-32				
Solene/Corona DC Closed Loop	SLCO64DC-80HE	Indirect Forced Circulation - Drainback	Solene - SLCO-32		Water		
	SLCO80DC-80HE		Solene - SLCO-40				
	SLCO80DC-80HE-XE		Solene - SLCO-40	50			
Solene/Corona Drainback	SLCO64DC-80DB		Solene - SLCO-32	None			
	SLCO80DC-80DB		Solene - SLCO-40				
Sup.plen.ergy Solar Water Heater	SESI-120-80	Indirect Forced Circulation - Antifreeze	Alternate Energy Tech. - AE-40	None	Glycol	PV Panel Controller	Tank Wraparound Heat Exchanger with a Double Wall
	SESI-80-40		Alternate Energy Tech. - AE-40				
Cascade	ECRD-64-80	Indirect Forced Circulation - Drainback	SunEarth - EC-32	None	Water	Differential Controller	Tank Wraparound Heat Exchanger with a Double Wall and Positive Leak Detection
Solaray	TE64C-80-1	Indirect Forced Circulation - Antifreeze	SunEarth - EC-32		Glycol		
	TE64C-80-PV		SunEarth - EC-32			PV Panel Controller	
	TE64P-80-1		SunEarth - EP-32			Differential Controller	
	TE80C-120-1		SunEarth - EC-40				
	TE80C-120-2		SunEarth - EC-40	50			
	TE80C-120-PV		SunEarth - EC-40	None		PV Panel Controller	
	TE80P-120-1		SunEarth - EP-40			Differential Controller	
Drainback Stainless HX	40-1T	Indirect Forced Circulation - Drainback	Synergy - TC-19.78	None	Water	Differential Controller	Plate Heat Exchanger with a Single Wall
	53-1T		Synergy - TC-26.52				
	53-2T		Synergy - TC-26.52	50			
	60-2T		Synergy - TC-19.78	50			
	S53-2T		Synergy - S26.68	50			
Thermomax Mazdon	Mazdon 40-R80	Indirect Forced Circulation - Antifreeze	Thermo Tech. - TMA-600-20	None	Glycol	Differential Controller	Tank Wraparound Heat Exchanger with a Double Wall and Positive Leak Detection
	Mazdon 50-R120		Thermo Tech. - TMA-600-50				
	Mazdon 60-R120		Thermo Tech. - TMA-600-30				
Thermomax Solamax	Solamax 60R-R120		Thermo Tech. - AST30				
	Solamax 60R-R80		Thermo Tech. - AST30				
	Solamax 70R-R120		Thermo Tech. - AST70				
Six Rivers Solar	SRS-100-2-40-PC-E	Indirect Forced Circulation - Drainback	SunEarth - SP-40	50	Water	Differential Controller	None

Certification for Tax Credit Eligibility?

Unless federal tax credits for SHW systems are extended, this may be the last year you can take advantage of Uncle Sam by installing a solar hot water system. Under the existing federal tax credit law, owners of new SHW installations are eligible for a tax credit of up to $2,000. But when it comes to what kind of certification is required to receive a break from the Feds, the waters are muddy. The law states that "the property" of residential solar water heaters must be certified by the SRCC, but it's unclear whether this refers to the collector or the whole system.

While we aren't aware of anyone being denied the federal tax credit from basing their claim on the OG-100 standard, some states and utility districts are requiring OG-300 ratings to be eligible for their incentives, including Arizona; California—Sacramento Municipal Utility District and City of Thousand Oaks; Colorado; Illinois; Nevada—Public Utilities Commission; and Oregon—Eugene Water and Electric Board and the City of Ashland.

System Selection Considerations

Once you've classified your climate, you can determine what system is right for your site. What's best? If you live in a freezing climate—or in a milder climate but just want to hedge your bets, use a drainback or antifreeze closed-loop system. If it doesn't freeze, or freezes are rare and mild, one of three "mild-climate" systems can fit your needs. Passive or active, PV or AC powered, these choices are up to you. Systems with quality components should have decades of good performance.

Access

Contributing editor **Chuck Marken** (chuck.marken@homepower.com) is a New Mexico-licensed plumber, electrician, and heating and air conditioning contractor. He has been installing and servicing solar thermal systems since 1979. Chuck is a part-time instructor for Solar Energy International and the University of New Mexico.

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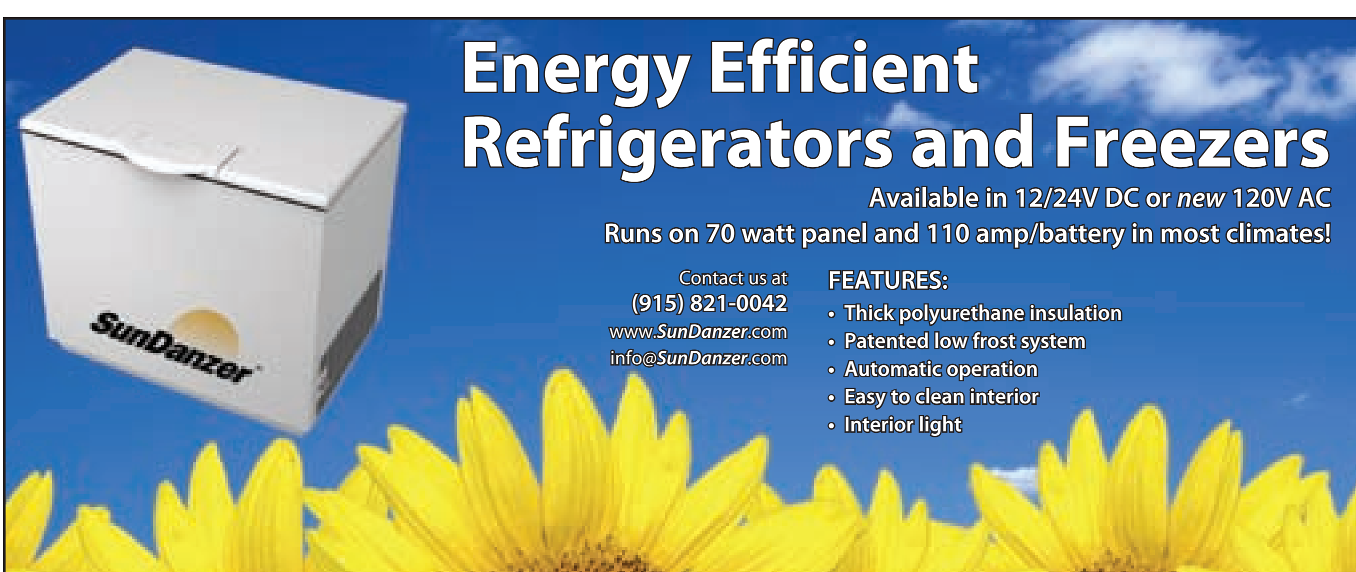
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To Fuse or Not to Fuse?

by John Wiles

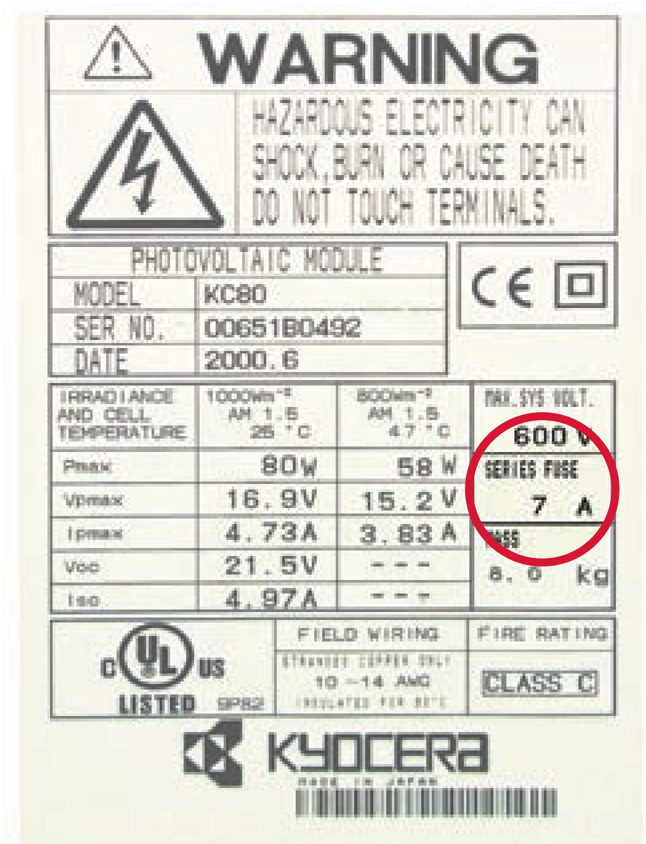
Sponsored by the U.S. Department of Energy

Most people agree that the *National Electrical Code (NEC)* improves with each edition. However, photovoltaic technology is still evolving, with new equipment, new wiring procedures, and new installation requirements being developed constantly. With these changes, and more inspectors and installers coming into the field every day, questions are bound to arise.

Some procedures and best approaches continue to stump both old timers and newcomers alike. The question of when to use overcurrent devices, such as fuses or circuit breakers, in direct-current circuits between PV modules and utility-interactive inverters is one in particular that plagues PV pros, since the solution is not directly found in the *NEC* but must be evaluated on a case-by-case basis.

Before answering this question, we first should address the issue that properly rated fuses and circuit breakers are functionally equivalent for this application, and are collectively known as overcurrent protective devices (OCPDs). This is true even though the required label on the back of certified/listed PV modules says "fuse."

In general, PV arrays operating at DC voltages above 150 volts (cold-weather, open-circuit voltage) may use fuses, and those operating below this voltage may use either fuses or circuit breakers. These applications are due to the ratings, availability, and cost of the different devices.



This PV module label states the maximum series fuse size.

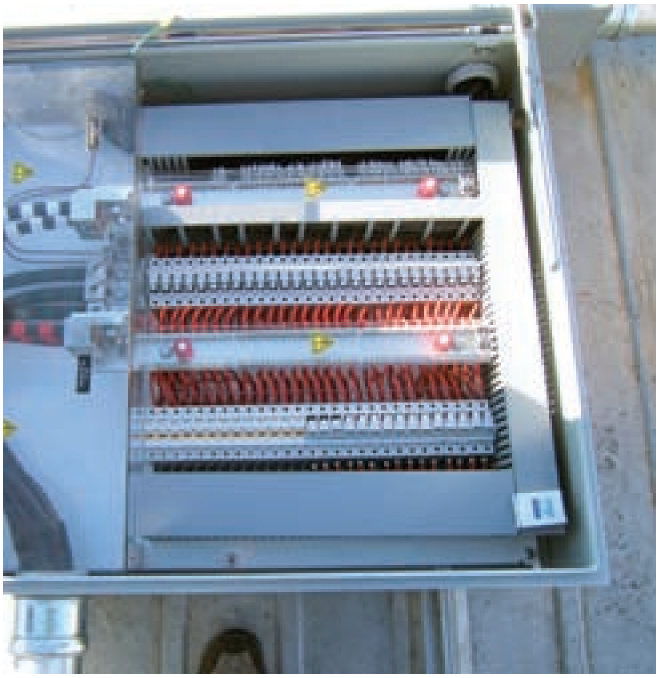
Protecting the Conductor

The *NEC* requires that, in most electrical systems, every ungrounded circuit conductor be protected from overcurrent that might damage that conductor. OCPDs provide that function. However, smaller utility-interactive PV systems may not need OCPDs in the DC circuits connected to the PV modules.

PV modules are current-limited devices, and their worst-case, continuous outputs, according to *NEC* Section 690.8(A)(1), are 1.25 times the rated short-circuit current (Isc). An exception in Section 690.9(A) allows conductors (typically rated at 1.56 times Isc) to be used with no OCPD where there are no sources of external currents that might damage that conductor.

However, if there are external sources of current that can potentially damage the internal module conductors, Underwriters Laboratories (UL), in its safety standard for modules (UL Standard 1703), has established that modules must have an external series OCPD. The *NEC* outlines protection for the wire, while the UL standard addresses protecting the module. Without an OCPD, the module can be damaged if reverse currents are forced through the module (due to an external or internal fault) in excess of the values of the maximum series fuse marked on the label on the back of the module.

External sources of current vary from system to system. They can originate from modules or module strings paralleled to the module of interest; from batteries backfeeding through charge controllers; or from utility currents backfeeding through utility-interactive inverters. (Note that the scenarios discussed below apply only to batteryless, utility-interactive PV systems.)



Above: A commercial-scale combiner box.
Right: An unfused DC PV disconnect, suitable for a single- or two-string grid-tied system.

Utility-Interactive Inverters & Utility Backfeed Currents

Most smaller utility-interactive inverters (10 KW or less) are designed so that they cannot backfeed current from the utility into array faults. These inverters have a maximum utility backfeed current of 0 amps. Although tests for abnormal operation and backfeeding exist, these tests do not rule out possible backfeed during an inverter's normal operation. Certification, usually in the form of a technical bulletin or technical specifications from the manufacturer, that the inverter cannot backfeed into an array fault under normal operation should be obtained from the inverter's manufacturer.

If the inverter can backfeed utility currents into the DC PV wiring, the *NEC* requires that an OCPD be installed in series with the output of all strings (or modules) to protect the cables and the modules from reverse currents. Inverters that have a maximum utility backfeed of something other than 0 A may be inverters larger than 10 KW or those designed for transformerless or bipolar operation. In cases where there are fused combiner boxes mounted at the array, an OCPD may also be needed at the inverter input, since the inverter can be a potential source of overcurrent. This OCPD will have a minimum rating based on the number of strings connected in parallel on that circuit and the short-circuit current of each string. This OCPD is sized to allow maximum forward currents from the array (all strings of modules) to pass through without interruption and to keep the overcurrent device from operating at more than 80% of rating.

Faults & Parallel Strings

The most common backfeed situation occurs in systems where there are multiple strings of modules connected in parallel. In the event of a fault, nonfaulted strings may be able to supply sufficient overcurrents (through the parallel connection) to damage either the conductors or the modules in the faulted strings. The inverter, for this example, has not contributed to the fault currents.

Fault currents can increase the normal current being carried in wires and modules. So the basic question becomes: How many PV modules or strings of modules can be connected in parallel and still meet *NEC* and UL requirements (marked on the back of each module) before an OCPD is needed on each module or string of modules?

UL requirements marked on the modules are based on the reverse-current tests described, which stipulate a maximum value for the OCPD. Section 110.3B of the *NEC* requires that installers follow the manufacturer's instructions and labels. However, lesser values can be used as long as they meet the *NEC* requirement of being 1.56 times the module short-circuit current (1.56 Isc) to protect the conductor associated with the module or string of modules (Section 690.8A and B).

In a few cases, module manufacturers have not met the code requirements, and the value of the module OCPD marked on the back of the module is less than 1.56 Isc. This poses a code conflict (110.3(B) vs. 690.8,9) and is an issue for UL to rectify.

String Scenarios

Assuming batteryless grid-intertie with an inverter that is certified not to backfeed via the AC source, let's examine some scenarios.

One string of modules. In a one-string system, no fusing would be required because no external sources of overcurrent exist. An unfused DC PV disconnect would be used on this type of system. The maximum series fuse rating that is marked on the back of the module is at least 1.56 Isc, and there are no sources of external currents that could damage the modules or the connecting cables (also rated at 1.56 Isc or higher).

Now let's look at a PV system with multiple strings of modules connected in parallel. Keep in mind that we are not determining the *rating* of any required OCPD; we are merely making some calculations that determine *whether or not* an OCPD is needed on each string of modules.

Two strings in parallel. Consider two modules or two strings of modules connected in parallel, then connected to the inverter input. Each string of modules can generate a maximum of 1.25 Isc. If a fault occurs in one string, the second unfaulted string can try to force 1.25 Isc amps into the faulted string. However, the modules in the faulted string can withstand currents up to at least 1.56 Isc or higher (if their marked series fuse rating is higher), and the conductors have an ampacity of at least 1.56 Isc or greater. Therefore, with only two strings of modules, no currents exist in the PV array that can damage the modules or the wiring—and no OCPDs are required.

Three strings in parallel. Now consider a system with three strings of modules connected in parallel. A fault in one string could see currents from the two other unfaulted strings. Each of these unfaulted strings could deliver up to 1.25 Isc under worst-case conditions for a total of 2.5 Isc (2 x 1.25 Isc). Suppose that the module manufacturer had the value of the maximum series fuse marked on the back of the module of exactly 1.56 Isc and the wiring was sized at exactly 1.56 Isc. The currents from the two unfaulted strings at 2.5 Isc would be far greater than the series fuse rating of the module and the ampacity of the conductors, risking damage. In this case, fuses in all three strings at a minimum value of 1.56 Isc would be required.

However, module manufacturers usually do not specify a marked maximum fuse value of *exactly* 1.56 Isc. Typically, the module will pass the UL reverse-current tests at a higher current, such as 15 amps. As an example, let's take a module that has an Isc of 5 amps and a marked value of the maximum series fuse of 15 amps. To protect the conductors, the interconnecting conductors between the modules must also have an ampacity of 15 amps, after the appropriate derating for conditions of use have been applied. In a system with three series strings of this module, the two unfaulted strings could deliver 12.5 amps (2 x 1.25 x 5). Since this current is less than the 15-amp ampacity of the conductors and is also less than the 15-amp maximum series fuse requirement marked on the back of the module, no fuses are required because no damage can be caused by overcurrent. The actual conductor ampacity would not have to be 15 amps but would have to be at least 12.5 amps after derating for conditions of use.

Determining Fuse Requirements

Series Strings	15 A Series Fuse		20 A Series Fuse
	5.0 A Isc	8.0 A Isc	1.5 A Isc
2	1.25 x 5 x 1 < 15	1.25 x 8 x 1 < 15	1.25 x 1.5 x 1 < 20
	No OCPD	No OCPD	No OCPD
3	1.25 x 5 x 2 < 15	1.25 x 8 x 2 > 15	1.25 x 1.5 x 2 < 20
	No OCPD	OCPD Required	No OCPD
12	OCPD Required	OCPD Required	1.25 x 1.5 x 11 > 20
			OCPD Required

In another example, let's look at a module rating of 8 amps Isc with the module wiring and module fuse rating still at 15 amps. The two unfaulted strings could send up to 20 amps (2 x 8 x 1.25). Because this exceeds the conductor ampacity and the ability of the module to withstand reverse currents, fuses would be required in each string of modules. The OCPD must be at least 1.56 Isc—in this case, 12.48 amps (1.56 x 8) and not more than 15 amps. A 15-amp OCPD would normally be used.

Modules with low Isc and high series fuse ratings. Some modules have a low short-circuit current and a high maximum series fuse rating. A module with a 1.5-amp Isc and a 20-amp maximum series fuse can have up to 11 strings of modules in parallel without any OCPD.

The bottom line is that when more than two modules or strings of modules are connected in parallel, a calculation should be done to see if an OCPD is required in each string. When three strings of modules are connected in parallel without fuses, the conductor ampacity may have to be greater than the normal 1.56 Isc, as described in *NEC* 690.9(A), exception (b). For a slightly more technical approach to these requirements and calculations, see Appendix J in *PV Power Systems and the 2005 NEC: Suggested Practices* manual (see Access).

Access

John Wiles (jwiles@nmsu.edu) works at the Institute for Energy and the Environment, which provides engineering support to the PV industry and a focal point for code issues related to PV systems. As an old solar pioneer, he lived for 16 years in a stand-alone PV-powered home—permitted and inspected, of course. This work was supported by the United States Department of Energy under contract DE-FC 36-05-G015149.

Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices by John Wiles • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html

PV Systems Inspector/Installer Checklist and previous *Code Corner* articles • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html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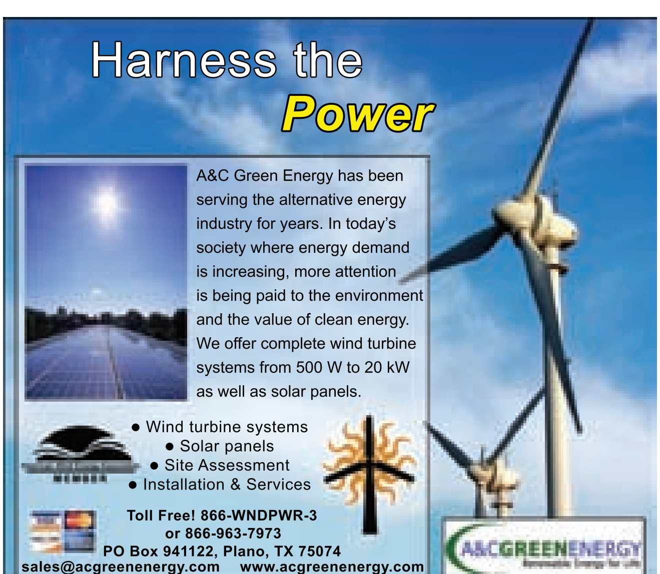
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Protecting the Interests of PV Pros

by Don Loweburg

The vast majority of PV pros—both the newcomers and the tried-and-true pioneers who have helped shape the industry—recognize the need for a trade organization to protect and support their interests. These men and women have helped the business grow into the mainstream industry that it is becoming today, and their position in the industry's continued evolution should be maintained. The question is: What trade group can step up to meet this need? Maybe it is time to reinvigorate this column's namesake organization, the Independent Power Providers.

In 1993, the Renewable Energy Development Institute (REDI) held a conference in Willits, California. The purpose of the conference was to explore various approaches and plans for commercializing PV. Attending the conference were utility personnel, state regulators, PV industry representatives, *Home Power* magazine staff, and solar installers. One intent of the conference was to discuss PV commercialization proposals funded by the U.S. Department of Energy (DOE) and the Utility Photovoltaic Group (UPVG), a consortium of utilities interested in pursuing PV as a utility-service option.

The basic premise held by UPVG and some within the PV industry was that utilities would be the natural market for the commercialization of PV. To this end, the utilities—with the assistance of UPVG and financial assistance from the DOE—would aggregate projects and execute bulk buys from PV manufacturers. It was assumed that the utilities would be a volume market and, over time, drive down the price of PV for all customers. Using this model of "sustained orderly development," PV manufacturers would be able to expand production to meet the needs of all players in a predictable, growing utility market.

UPVG's commercialization plan was to first focus on off-grid applications as a means of familiarizing utilities with PV. It was understood that this market itself would be insufficient to bring PV to economic parity with grid power, but would be a first step—to be followed later with the commercialization of grid-connected PV systems. UPVG's plan was that regulated utilities would offer PV systems or services for sale to off-gridders as a means to bring them into the utilities' rate base.

This proposal did not sit well with two groups attending the REDI conference. First, California state regulators pointed out a possible conflict with California Public Utility Code 2775.5, which would "deny the authorization sought (by an electric corporation) if it finds that the proposed program will restrict competition or restrict growth in the solar energy industry." Further, the statute stipulated that proposed authorization would only be granted for a program that "would accelerate the development and use of solar energy systems."

The second group opposed to the UPVG proposal was existing PV installers. Fifteen years ago, the market for PV was primarily off grid and installers saw no benefit to themselves if utilities were to enter the PV installation business—in fact, many of them viewed it as giving the utilities an unfair advantage within their own industry.

Preserving the Pros' Perspective

A majority of installers at the conference were adamant in their opposition and decided to form a formal group to represent their interests. Independent Power Providers (IPP) was incorporated as a nonprofit public benefit corporation in California on September 30, 1994, to "promote and encourage the use of renewable energy by developing opportunities for end-user ownership of renewable energy generation sources and encouraging a professional installation infrastructure…"

That same year, Southern California Edison (SCE), one of the three major California-regulated electric utilities, proposed to market PV systems to off-grid customers in keeping with UPVG's strategy to commercialize high-value applications first. To do so, SCE sought permission from the California Public Utilities Commission (CPUC) via an "advice letter" (AL), which is intended to be used only for minor changes in already-in-place policy. SCE framed their plan as an experimental, three-year pilot program.

IPP responded to the AL, protesting the plan. Specifically, IPP asserted that SCE's sale of off-grid systems would not only restrict competition but also restrict the development and use of PV systems in the state. The response also pointed out that about 20 existing PV companies in California already specialized in the installation of off-grid systems. IPP also questioned the need and legality of a regulated utility entering an already-competitive market for PV installation.

IPP's protest resulted in limited success. The CPUC issued a stipulated decision, allowing SCE to market off-grid systems but requiring them to bid the jobs out to PV contractors. Additionally, the regulators required SCE to hold semiannual public meetings at which the progress of the program would be evaluated. Within these meetings, it was understood that SCE needed to show two things: that their program was not restricting competition or restricting growth in the solar industry, and that their program was accelerating the development and use of solar energy systems.

IPP's Solar Scorecard

IPP's action over the past 15 years has strongly influenced many aspects of the PV industry and market. Here's a sampling of the stances that IPP has taken:

- Opposed utility ownership of PV resources on customer sites.
- Supported net metering in California and nationally.
- Supported rebates and incentives going directly to the customer.
- Supported simplified interconnection to the utility.
- Opposed unnecessary extra disconnects. (California's PG&E finally dropped that requirement in 2007.)
- Opposed the levy of "standby" and "demand" charges by California utilities on net-metered systems.
- Supported customer ownership of renewable energy credits (RECs).

At the second REDI conference in 1995, as a rebuttal to the UPVG plan, IPP presented its own commercialization plan. The IPP plan included net metering, simplified utility interconnection rules, rebates delivered to the customer, UL standards and ratings for equipment, and standards for installers. IPP and other organizations continued to promote the ideas central to its plan, eventually resulting in some of the earliest commercialization regulations and incentives in the nation (see "IPP's Solar Scorecard" sidebar).

The second phase of the UPVG commercialization plan was the development of home-scale, grid-connected projects. Once again, IPP led the opposition when SCE stated its desire to pursue grid-tied systems as a customer sales option. The result was that IPP and SCE negotiated an agreement that IPP would not protest if SCE pursued an experimental grid-tied PV program structured like the off-grid program.

Overall, only a few off-grid and grid-connected systems were sold by SCE, and both programs were discontinued mainly because they were not economical for the company. As IPP installers had long asserted, the utility's involvement resulted in higher-cost PV systems—which few customers could afford.

During the late 1990s, California utilities underwent restructuring. Given the minimal success of SCE's PV programs and the overwhelming organizational demands of restructuring, utility PV commercialization efforts faded. In 1996, the California legislature created a net metering law; in 1998, it established a customer rebate program. The new consensus held in the industry was that on-site, customer-owned (or third-party-owned) PV would be the commercialization pathway—the model that remains today.

What's Next?

Veteran Virginia PV-pioneer Jeffrey Yago said in a recent forum message, "We are dealing with many common issues, like the lack of response from manufacturers when they discontinue products we really need, or code groups that listen and then go on and do what they want, and states that make rules right out of never-never land. However, a single voice is just not being heard, and it is getting worse as everything gets passed down to us in a take-it-or-leave-it dictate."

Central to the creation of IPP was the need to give voice and status to PV pioneers whose interests—and livelihoods—were being threatened as regulated utilities attempted to take over the market. While IPP has served its original mission, many valuable projects, purposes, and installer issues still remain. Professional installers frequently cite the need for a trade association to tackle such issues, but none have been able to step forward to organize it. Can IPP be that organization? The answer really depends on whether there is sufficient interest and energy to make it so. The current IPP board is eager to facilitate any such transition.

Access

Don Loweburg (don.loweburg@homepower.com) is a solar pioneer in central California. He owns and operates Offline Independent Energy Systems, and sits on the boards of the California Solar Energy Industries Association and the North American Board of Certified Energy Practitioners (NABCEP).

Getting FIT

by Michael Welch

The recent changeover to a "greener" Congress is showing some benefits to the renewable energy world.

Congress is now drafting bills to form federal policies supporting household and small-scale commercial RE that go way beyond net metering. Feed-in tariffs (FITs) may be the next promising step for RE development in the United States.

Whereas net metering is designed to offset household or business usage, renewable energy FITs typically provide a premium price per KWH (as in production-based incentives, or PBIs) when a system produces *more* electrical energy than the building consumes. Some programs also pay that premium for offsetting usage even before the using/producing breakeven.

Incentives for both of these government-mandated programs—net metering and FITs—are funded through surcharges that all utility customers pay. The amounts used to fund these programs are charged on a per-KWH basis and lumped in with the utility's "public purpose programs." These have also been established to help cover the costs of providing assistance to low-income utility customers and financing energy-efficiency programs.

Growing the RE Garden

State-by-state net billing laws have served the renewable energy industry quite effectively so far, as indicated by the increasing number of home-scale PV and wind installations—and professional installers—in the states with effective rules, compared to those states without net billing. From an industry perspective, the point of those laws was to give a budding industry a little "fertilizer" to help it grow and gain solid roots to become self-sustaining.

Now that the RE industry has established itself in the United States, it is time to propagate it by including those states that have not had the political will to establish their own effective programs. More nurturing incentives could shift the industry from its current status of "present and ready" to the next stage: rapid growth of manufacturing facilities, dealers, and installers and, with that, price decreases.

The timeliness of this next step will be important to uprooting the weed of climate change. We must speed up necessary greenhouse gas reductions, or else risk reaching a tipping point beyond which global warming does not have a reasonable recovery scenario. Accelerating the growth of RE by taking incentives to the next phase can help achieve this goal.

Feed-in tariffs are nothing new—Europe's successful systems of "rate-based incentives" have long been the envy of RE advocates in the United States—so understanding how they accomplish industry growth here should be predictable. The German model, perhaps most often heard of, has been triumphant at increasing the installation of RE in that country. Only one European country has more installed PV per capita than Germany's approximately 30 watts peak, and that is Luxembourg, with more than 50 Wp per capita from its wildly successful, but temporary, rate-based incentives program.

The German model was so successful that its programs (along with a couple in other countries) temporarily created a worldwide shortage of PV modules. German installers were willing to pay higher-than-normal *retail* prices for modules—even within the wholesale market. Shipping containers full of modules were being resold into Europe from other countries—even coming directly from U.S. retailers and distributors—because the price was right.

The key to the success of these programs was in making the tariffs as attractive as possible. The higher the profit potential for would-be system owners, the more likely they are to invest in systems. Considering the immediacy and risks of continued climate change, the price of PV energy generated on site could easily be valued at 50 cents per KWH or more—admittedly a seat-of-pants estimate, but in line with the German model and enough to make even the most thrifty of utility customers sit up and take notice.

United States FITs Next?

Leaders of both houses of Congress have drafted FIT bills. As of this writing, no bills have been introduced, but citizen input is being sought. In the House, Representative Jay Inslee is drafting The Clean Energy Buy-Back Act, which would amend the Public Utility Regulatory Policies Act (PURPA)

Presidential Promise

While the threat of vetoing legislation not supported by the current administration still exists, bills introduced now may not even make it all the way through the current legislative session, which ends in the fall for both houses. This is good news, since this could delay the bills until after a new president is sworn in. The three viable presidential candidates are all more likely to support RE and climate-change legislation compared to the current administration. It is time to raise our hopes for a renewable energy, climate-neutral future, and to back them up by encouraging our Congressional representatives to work harder than ever to make it happen.

to require utilities to enter into 20-year fixed-rate power purchase agreements and to set those rates to provide system owners with a reasonable rate of return on investment. Though the PBI amounts that have been so effective in Europe have not been specified in these bills, it would be a huge step forward as envisioned.

Senator Bernard Sanders of Vermont is working on a bill that's similar to the Inslee draft in intent and content. His National Renewable Energy Sources Act would make PBIs the law in all states. Both bills would amend PURPA, set rates, and spread out the costs among ratepayers, though no details exist yet. Neither draft precludes other state, federal, or local incentive programs, such as rebates and tax credits.

Right now we have a unique opportunity to chime in before these drafts are finalized. Make sure that the legislators' staff understands the need for high PBIs if they truly want to see results as effective as the European programs. See Access for the contact information for Congressional staffers who are working on these bills. Then take the time to call your own representatives in Congress and ask them to sponsor the bills when the time comes. While you're at it, be sure to put in a plug for renewing the federal tax credits, which will otherwise expire on December 31, 2008.

Access

Michael Welch (michael.welch@homepower.com) has been working for a clean, safe, and just energy future since 1978 as a volunteer for Redwood Alliance and with *Home Power* magazine since 1990. He will be spending the next year in Sacramento, California, where he hopes to help hold the Governator to his RE promises.

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Senator Bernard Sanders's Staff Contacts:
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Home Field Advantage

by Kathleen Jarschke-Schultze

I've often been amused by the "green speak" that's grown up around diet choices. There are the vegans (no animal or animal by-products of any sort are consumed), the vegetarians (no food from flesh), the aquarians (eat seafood), pesco-pollo folks (eat fish and poultry), the beady-eyed vegetarians (if it has beady eyes, they'll eat it), the omnivores (eat anything and everything), and the opportunavores (eat what's placed in front of them). Now there are some new words in the lexicon of diet choices.

Living la Vida Locavore

I've just finished listening to the audio book of Barbara Kingsolver's *Animal, Vegetable, Miracle: A Year of Food Life* (www.animalvegetablemiracle.com) for the second time. It is so inspiring and informative on many levels. Barbara's family of four chronicles a year living as *locavores.*

A locavore (sometimes called *localvore*) is someone who gets their food—animal or vegetable—from within 50, 100, or 150 miles of their home, depending on their region. Their larder comes generally from their own gardens, a CSA (community-supported agriculture) farm, and local farmers markets. Locavores support their local economy by local purchasing. This is also called "food patriotism."

Groovin' on Sole Food

An *ethicurian* is someone who seeks out tasty things that are also sustainable, organic, local, and ethical—SOLE food, for short. This is the definition at www.ethicurian.com, whose motto is, "Chew the right thing."

After seeing the video clips of the cruelty to cows at a Chino, California, beef-processing plant, which resulted in the recall of 143 million pounds of frozen beef, I'm a converted ethicurian. The undercover video, shot by the Humane Society of the United States, showed workers abusing "downer" animals that were apparently too sick or injured to walk into the killing box.

Federal regulations call for keeping downed cattle out of the food supply because they may pose a higher risk of contamination from *E. coli*, salmonella, or mad cow disease, as a result of their weakened immune systems and being forced to wallow in their own feces. Of course, after the fact, we found out that a lot of the meat from this plant was sold to school lunch programs and had been eaten by children already.

In the United States, about one-tenth of 1% of beef cattle are tested for mad cow disease. In Europe and Japan, 100% are tested. The human form of mad cow disease happens when infected cows are eaten by people. The cows get it from eating ground-up cow waste. After the mad cow scare, the United States banned feeding cow waste to cows. Now they feed it to chickens and pigs. And *then* they feed chicken waste to cows. This process does not eliminate mad cow disease. It simply travels through the literal loops—as viable as ever.

Shop, Shop Around

Growing your own meat is a big undertaking. If you can do it, great. If you can't, the next best thing is to know the person who raised it. Right now my Sun Frost freezer is holding half of a hog my husband Bob-O and I bought from people we know. Many local markets now offer a number of "ethical" choices for meat and fish. Farm-raised, grass-fed, pasture-finished, free-range—we all should become familiar with these terms if we're into SOLE food.

Of course, few of us can grow all our own food—even those of us with big gardens can't grow every single thing we want. Weather and geography intervene. To eat seasonally where I live would take a lot of canning, freezing, and drying. I am lucky that there is a wealth of farmer's markets, local vegetable stands, and natural food stores around here. To find local food supplies in your area, visit www.localharvest.org.

Sustainability Grows

Michael Pollan, author of *The Omnivore's Dilemma: A Natural History of Four Meals* and *In Defense of Food: An Eater's Manifesto* (www.michaelpollan.com), has a few suggestions. He says don't eat anything your great-grandmother wouldn't recognize as food. Similarly, he advises, if a packaged product contains more than five ingredients, it's probably *not* food. He removed the lawn at his home in the Bay Area and put in a vegetable garden.

I know people who are and have been ethicurians before there was a word for it. Vegetarians Sue Robishaw and Steve Schmeck (www.manytracks.com) experimented with *really* local food, living for a year on what they could raise themselves. This was years ago, and I remember Sue saying vegetable oils were a stumbling block for them.

A couple of years ago, I took Larisa Walk's workshop, "Eating From Your Garden Year-Round," at the Midwest Renewable Energy Fair. She and her partner Bob Dahse have the most wonderful Web site (www.geopathfinder.com). For their tips on growing local, click on "Veggie Homesteading" and "Food Preservation."

Keeping It Real

This cascading revelation about locavorism has impressed me. I've been growing only open-pollinated seeds for years (www.bountifulgardens.org). These are seeds that can be saved from the mother plant and will grow true when planted. Heirloom varieties, as they are often called, are enjoying increasing popularity. I try my hand at saving some seeds, the easy ones. I had a friend who told me once to let one of everything go to seed in my garden. I always have a lot of volunteers—plants, that is. I've also learned that when the lettuce volunteers come up, it is time to plant lettuce. When the potato volunteers break ground, it is time to plant potatoes.

My locavore challenge is to figure out what produce I end up buying at the grocery store and to see if I can grow that particular variety at my house. For my kimchee recipe, I can make or grow every ingredient except napa cabbage. But this year I bought a slow-bolting, open-pollinated variety. If I can get it to head up in the dry heat, I'll not only have my kimchee cabbage, but also will be able to save seeds and add them to my seed bank for next year. Of course, that means I need to organize my collecting better. While cleaning off my desk recently, I came across a taped-shut, half-used envelope of "Cabernet Lettuce '07."

Green Food Housing

I have been using a small lean-to greenhouse for starting seeds. I framed in the area beneath the 3-foot overhang on the southeast side of our house, and put up fiberglass greenhouse panels and a door at both ends. When we replaced our windows in the house with double-paned units, I mounted one of the old windows above one of the doors for ventilation.

For a planting table, I built a long, two-shelved bench and covered it in hardware cloth. For years, this is where I

Regional Eating

In winter, when you shell out a few bucks to buy a tomato, cantaloupe, or grapes at your supermarket, the real costs of growing and shipping are not revealed. How much did it cost to get them there? The importer doesn't care. They get to deduct the cost of transport. But resources are being used. Oil is being used up.

Even within the United States, enormous amounts of fuel are used to transport factory farm produce across our country. CUESA (Center for Urban Education about Sustainable Agriculture; www.cuesa.org) estimates that the average American meal travels 1,500 miles from field to fork. It is estimated that if every family in the country ate just one meal per week from locally procured food, we could save 1.1 million barrels of oil per week.

Eating regionally and getting your food locally not only reduces reliance on fossil fuel, but it helps keep dollars local, stabilizing regional economies. An additional benefit is that it helps keep our communities healthier—fresh, organic, whole, locally harvested foods have more vitamins and minerals than their packaged counterparts and none of the pesticide residue possible in factory-farmed or imported foods.

Choosing local rather than processed foods also keeps trans fats and high-fructose corn syrup, which have been linked to heart disease and diabetes, off our shelves and out of our diets. Adult-onset diabetes has been renamed Type II diabetes because so many children have become victims. Sadly, for the first time in history, the current generation of children is not expected to have a longer life span than their parents.

have started my seedlings. My problem has been the mice that come and eat my seedlings or dig up the seed before it has even sprouted through the dirt. The greenhouse is so ramshackle that I could never completely seal it against rodents, and the whiskered critter invasion has been so discouraging that I had taken to buying organic starts rather than starting my own.

So this year I bought an 8- by 7.5-foot greenhouse. Since it is constructed as one piece, I'm hoping it will end my mouse problems and enable me to enlarge my gardening repertoire. I'm trying several new varieties this year, thinking ahead to saving seed and preserving the crop. I've taken to buying a vegetable variety to see if we like it, and then see if I can grow it.

Chock o' Choices

There are a lot of factors involved in being a locavore or becoming an ethicurian. It doesn't have to be done all at once. Awareness is the first step. It's a lot of commitment, effort, and self-education to make choices that support the ideals you believe in. I have to admit that it's going to be hard giving up bananas. Maybe I can relieve my conscience by just buying the aged ones that are already wearing red discount ribbons. And thank goodness for fair-trade goods, 'cause we're not ready to give up coffee—or chocolate, for that matter.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is enjoying her new greenhouse at her off-grid home.

RE happenings

U.S.A.

CALIFORNIA

Jun. 9–11, '08. San Francisco. PV System Design—Producing PV design documents. For engineers & designers. Info: 707-869-9391 • www.sunengineer.com/workshops.htm

Jun. 18–20, '08. San Diego, CA. PV Summit 2008. Industry & market trends. Updates on silicon supply, PV technologies, concentrated PV, next generation thin-films, dye-sensitized solar cells, organic PV & emerging applications. Info: www.intertechpira.com

July 15–17, '08. San Francisco. Intersolar North America. Exhibition focuses on photovoltaics, solar thermal technology, and solar architecture. Seminars & workshops on current industry trends. Info: Solar Promotion International GmbH • 415-248-1257 • wagner@intersolar.us • www.intersolar.us •

Jul. 22–24, '08. San Jose, CA. Plug-In 2008 Conf. & Expo. Latest tech advances, market research & policy initiatives on plug-in hybrid-electric vehicles (PHEVs). Info: www.plugin2008.com

Aug. 10–14, '08. San Diego, CA. Solar Energy Applications, a part of SPIE Optics+Photonics conf. Tech presentations & courses on PV; R&D of solar concentrators & solar hydrogen. Info: www.spie.org

Aug. 16–17, '08. Hopland, CA. SolFest. RE booths, workshops & kids' activities. Food & entertainment. Info: www.solfest.org

Oct. 13–16, '08. San Diego, CA. Solar Power 2008. Conference & expo. Info: SEIA • 202-296-1688 • mglunt@solarelectricpower.org • www.solarpowerconference.com

Arcata, CA. Workshops & presentations on RE & sustainable living. Info: Campus Center for Appropriate Technology • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

Hopland, CA. Workshops on PV, wind, hydro, alternative fuels, green building & more. Solar Living Institute • 707-744-2017 • sli@solarliving.org • www.solarliving.org

COLORADO

Sept. 20–21, '08. Fort Collins, CO. Rocky Mt. Sustainable Living Fair. Exhibits, workshops, RE, alternative vehicles & more. Info: Rocky Mt. Sustainable Living Assoc. • 970-224-3247 • kellie@sustainablelivingfair.org • www.sustainablelivingfair.org

Crawford, CO. Solar Energy for Do-It-Yourselfers '08 workshops: Jun. 6–7: Solar Ovens, Cookers & Dryers; Jun. 14–15: Intro to PV; Jun. 27–29: Batch Solar Water Heaters; Jul. 12–13: Solar Hot Air Collectors. Info: Our Sun Solar • 970-921-5529 • www.solarenergyclasses.com

Carbondale, CO. Workshops & online courses on PV, water pumping, wind, RE businesses, microhydro, solar hot water, space heating, alternative fuels, straw bale building, green building, women's PV courses & more. Info: Solar Energy Intl. • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

FLORIDA

Melbourne, FL. Green Campus Group meets monthly to discuss sustainable living, recycling & RE. Info: fleslie@fit.edu • http://my.fit.edu/~fleslie/GreenCampus/greencampus.htm

ILLINOIS

Aug. 9–10, '08. Oregon, IL. IL RE & Sustainable Lifestyle Fair. RE booths, workshops, tours & kids' activities. Food & entertainment. Info: www.illinoisrenew.org

IOWA

Sep. 13–14, '08. Cedar Falls, IA. I-Renew Energy Expo. Workshops, exhibits, food, entertainment. Info: See listing below.

Iowa City, IA. Iowa RE Assoc. meetings. Info: 319-341-4372 • irenew@irenew.org • www.irenew.org

MASSACHUSETTS

Sep. 15–17, '08. Boston. Alternative Energy Sources & Technologies. Conf. & exhibition on biomass, biofuel, geothermal, hydro, hydrogen, solar, wind & waste-to-energy. Info: www.cardellexpo.com

Auburn, MA. Seminars: Solar Basics, PV, Hot Water, Wind, RE & more. Info: CNE Solar Store • 508-832-4344 • peter@cnesolarstore.com • www.cnesolarstore.com

Hudson, MA. Workshops: Intro to PV; Advanced PV; RE Basics; Solar Hot Water & more. Info: The Alternative Energy Store • 877-878-4060 • support@altenergystore.com • http://workshops.altenergystore.com

MICHIGAN

Jun. 27–29, '08. Onekama. MI Energy Fair. RE, EE, green building & alternative vehicle workshops & vendors. Food & music. Info: www.glrea.org

Jul. 3–6, '08. Rothbury, MI. Music festival. RE, climate action, sustainable living. Info: www.rothburyfestival.com

West Branch, MI. Intro to Solar, Wind & Hydro. 1st Fri. each month. System design & layout for homes or cabins. Info: 989-685-3527 • gotter@m33access.com • www.loghavenbbb.com

MISSOURI

New Bloomfield, MO. Workshops, monthly energy fairs & other events. Info: Missouri Renewable Energy • 800-228-5284 • info@moreenergy.org • www.moreenergy.org

MONTANA

Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV & more. Info: Sage Mountain Center • 406-494-9875 • www.sagemountain.org

NEW HAMPSHIRE

Rumney, NH. Green building workshops. Info: D Acres • 603-786-2366 • info@dacres.org • www.dacres.org

NEW MEXICO

Jun. 27–29, '08. Taos, NM. Taos Solar Music Festival. Solar-powered music, food & displays. Info: www.solarmusicfest.com

Sep. 20–21, '08. Albuquerque. Solar Fiesta. RE & EE exhibits & workshops. Info: www.nmsea.org

Six NMSEA regional chapters meet monthly, with speakers. Info: NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NEW YORK

Jun. 21–22, '08. New York City. Renewable Energy Finance Forum. Info: www.euromoneyenergy.com

NORTH CAROLINA

Aug. 22–24, '08. Fletcher, NC. Southern Energy & Environment Expo. RE displays, exhibits & presentations. Info: www.seeexpo.com

Beech Mt., NC. Western NC RE Initiative 2008 workshops: Jun. 20–21: Community-Scale Biodiesel Production; Jul. 11–12: Domestic Solar Water Heating; Aug. 27: PV & the National Electric Code; Oct. 4–5: Microhydro. Info: WNCREI • 828-262-7333 • wind@appstate.edu • www.wind.appstate.edu

Saxapahaw, NC. Solar-Powered Home workshop. Info: Solar Village Inst. • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

OHIO

Sep. 1, '08. Johnstown, OH. Ohio Green Living Fayre. RE, sustainable building, alternative fuels, food, music, kids stuff & more. Info: jay@bluerockstation.com • www.ohiogreenliving.org

OREGON

Jul. 25–27, '08. John Day, OR. SolWest RE Fair. Exhibits, workshops, speakers, family day, music, alternative transportation & Electrathon rally. Info: EORenew • 541-575-3633 • info@solwest.org • www.solwest.org

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. Info: Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA

Sep. 20–21, '08. Kempton, PA. PA RE & Sustainable Living Festival. RE, natural building & sustainable ag; workshops, speakers, exhibits, vendors, music & kids' activities. Info: www.paenergyfest.com

Philadelphia Solar Energy Assoc. meetings. Info: 610-667-0412 • rose-bryant@verizon.net • www.phillysolar.org

RHODE ISLAND

Jun. 7, '08. Coventry, RI. Sustainable Living Festival & Clean Energy Expo. RE workshops, vendors & music. Info: www.livingfest.org

TENNESSEE

Summertown, TN. Workshops on PV, alternative fuels, green building & more. Info: The Farm • 931-964-4474 • ecovillage@thefarm.org • www.thefarm.org

TEXAS

Aug. 1–3, '08. Marathon, TX. Living With Nature, Sustainable Living & Green Building Festival. Lectures, workshops, tours & vendor displays on eco-construction, off-grid living & more. Info: LWN • 432-386-4257 • sowelo2000@yahoo.com • www.livingwithnature.net

Sep. 26–28, '08. Fredericksburg, TX. RE Roundup & Green Living Fair. Exhibits, speakers & workshops on RE, green building, green ag & EE. Info: www.theroundup.org

El Paso Solar Energy Assoc. Meets 1st Thurs. each month. Info: EPSEA • 915-772-7657 • epsea@txses.org • www.epsea.org

Houston RE Group, quarterly meetings. HREG • hreg@txses.org • www.txses.org/hreg

VERMONT

Jul. 11–13, '08. Tinmouth, VT. SolarFest. Solar powered music & RE festival. Info: www.solarfest.org

WASHINGTON STATE

Jul. 18–19, '08. Shoreline, WA. Shoreline Sustainable Living & RE Fair. Exhibitors & speakers. Info: www.shorelinesolar.org

WISCONSIN

Jun. 20–22, '08. Custer, WI. RE & Sustainable Living Fair (aka MREF). Exhibits & workshops on solar, wind, green building, alternative transportation, energy efficiency & more. Home tours, silent auction, Kids' Korral, entertainment, speakers. Info: See MREA listing below.

Custer, WI. MREA '08 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Masonry Heaters; Wind Site Assessor Training & more. Info: 715-592-6595 • info@the-mrea.org • www.the-mrea.org

Amherst, WI. Artha '08 workshops: Intro to Solar Water & Space Heating System, Installing a Solar Water Heating System, Living Sustainably & more. Info: 715-824-3463 • chamomile@arthaonline.com • www.arthaonline.com

INTERNATIONAL

GERMANY

Jun. 10–11, '08. Munich. PV Industry Forum. Solar developments exhibition & forum. Info: Solar Promotion GmbH • 49-07231-58598-0 • www.pvindustry.de

Jun. 12–14, '08. Munich. Intersolar 2008. Solar developments exhibition & forum. Info: www.intersolar.de

NICARAGUA

Jul. 21–31, '08. Totogalpa. Solar Cultural Course. Lectures, field experience & ecotourism. Info: Richard Komp • 207-497-2204 • sunwatt@juno.com • www.grupofenix.org

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Arkansas

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California

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California, cont.

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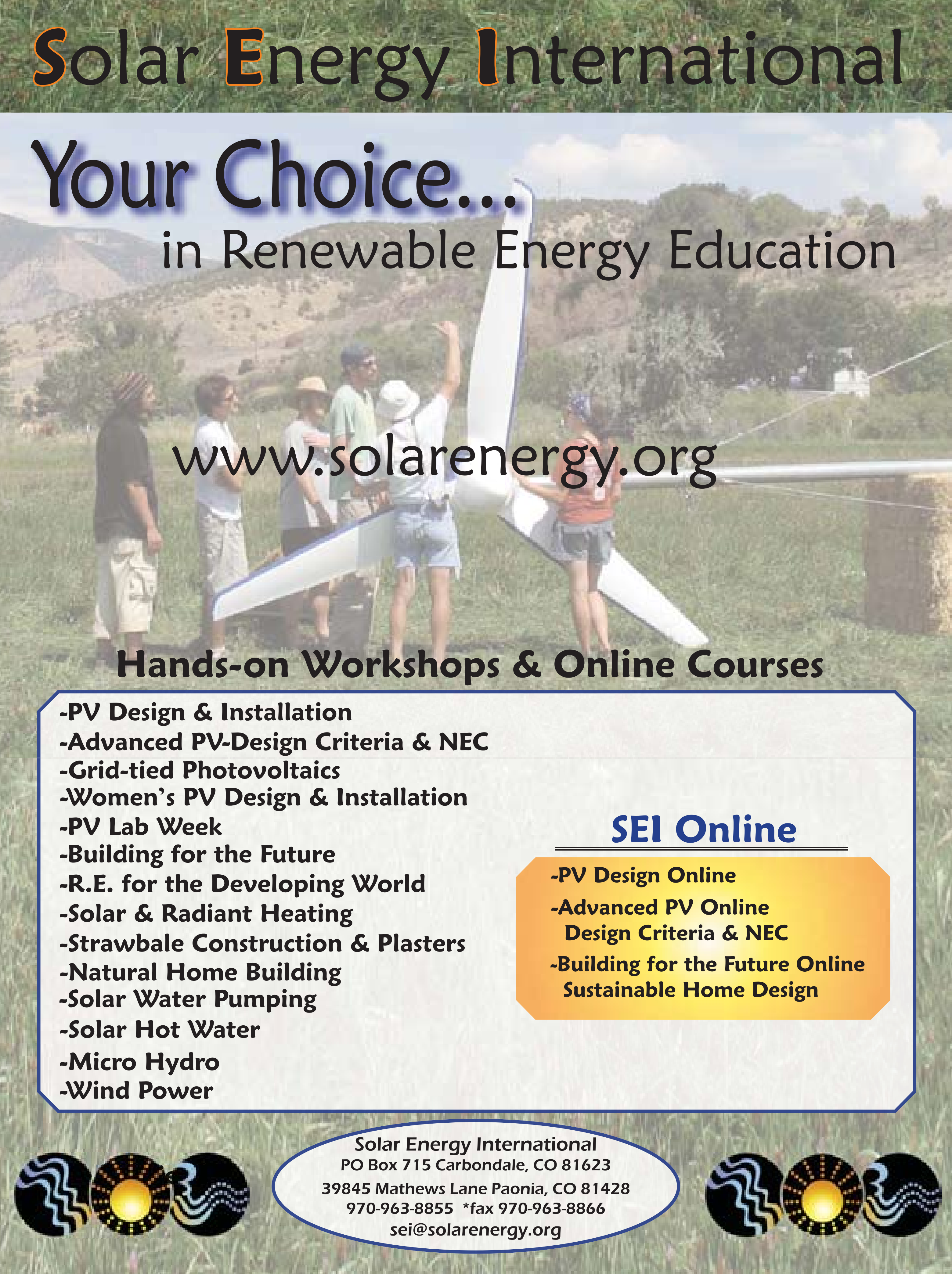
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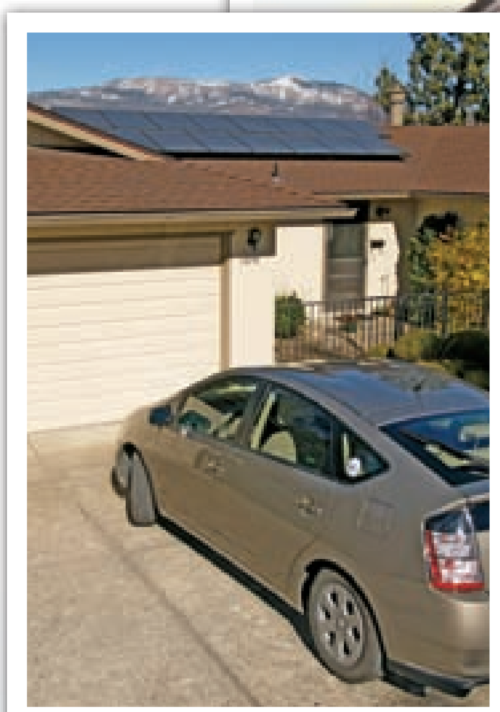
Meg Thomas is a grandmother—and at first glance, a pretty conventional one. She goes by "Mammie" or "Nanna," and wears her hair in silver curls—but don't be fooled by her typical appearance. This church-going grandmother of seven is a feisty, forward-thinking one.

Shawn Schreiner (2)



A woman ahead of her time, Meg Thomas invested in PV, energy efficiency, and efficient transportation—for the sake of future generations.

Other grandmothers might drive a late-model Cadillac or luxury Town Car. Not Meg. At 85, she cruises around in a Toyota Prius. "It's such a neat car. Not only do I feel 'with-it,'" she laughs, "driving a hybrid or electric vehicle is the right thing to do."

Thomas is proud that her car stands out in town and even more pleased that she can drive up to 54 miles on a gallon of gasoline. Her commitment to conservation doesn't end with her wheels, though. When she's not doting on her grandchildren or great grandchildren, playing bridge, or tending to her vegetable garden, she's counting the kilowatt-hours generated by the solar-electric system that she had installed on her home in 2004.

Thomas got serious about renewable energy a few years ago—after downsizing to a modest, single-story home "to save her bones and save energy." She heard that the city offered a variety of services and incentives to help residents improve the efficiency of their homes. "It was easy," she says. "I just made a few calls, and before I knew it, I had guys in here using blowers and all sorts of gadgets to find all the air and energy leaks."

The energy audit showed that her 1975 home would require several upgrades to achieve optimal efficiency. Meg didn't hesitate. She hired professionals to replace the heating ducts, install double-pane windows, and amend the insulation. But she didn't stop there. Next came a new roof and a batteryless, grid-tied 3.3 KW solar-electric system—complete with 15 Sanyo photovoltaic (PV) modules that feed into a Fronius IG3000 inverter.

"We waste so much and have too much," Thomas says. "Instead of buying pointless gifts for my grandchildren or great grandchildren at holidays and birthdays, I decided to give them the gift of solar energy and help make the world a better place for them."

Like many people living on savings and social security, Meg stretches every dollar with coupons and senior-citizen discounts. When it came to investing in energy, she was equally thrifty—taking advantage of city, state, and federal incentives that covered more than half of the cost associated with the efficiency upgrades and PV system.

Meg paid roughly $10,000 for the PV system, which generates about 3,300 KWH of electricity annually. Any power in excess of her needs is sold back to the grid. During the summer, her meter spins backward, earning her roughly $7 per month. "Even in the darkest months of winter, I have the lowest electric bill of all my friends," she says.

Although Meg wasn't concerned if the system paid for itself in her lifetime, rebates and incentives add up for a quick payback—about 10 years. But for her, this wasn't the point. "Nothing that I've ever spent money on has paid me back, so why should that matter now? It's an investment in our planet," she says. "People always ask, 'Do you think the system will pay for itself?' I say, 'I don't care if it pays me back. It will pay the world back.'"

—Robert Plain (bobplain@yahoo.com),
with Kelly Davidson (kelly.davidson@homepower.com)

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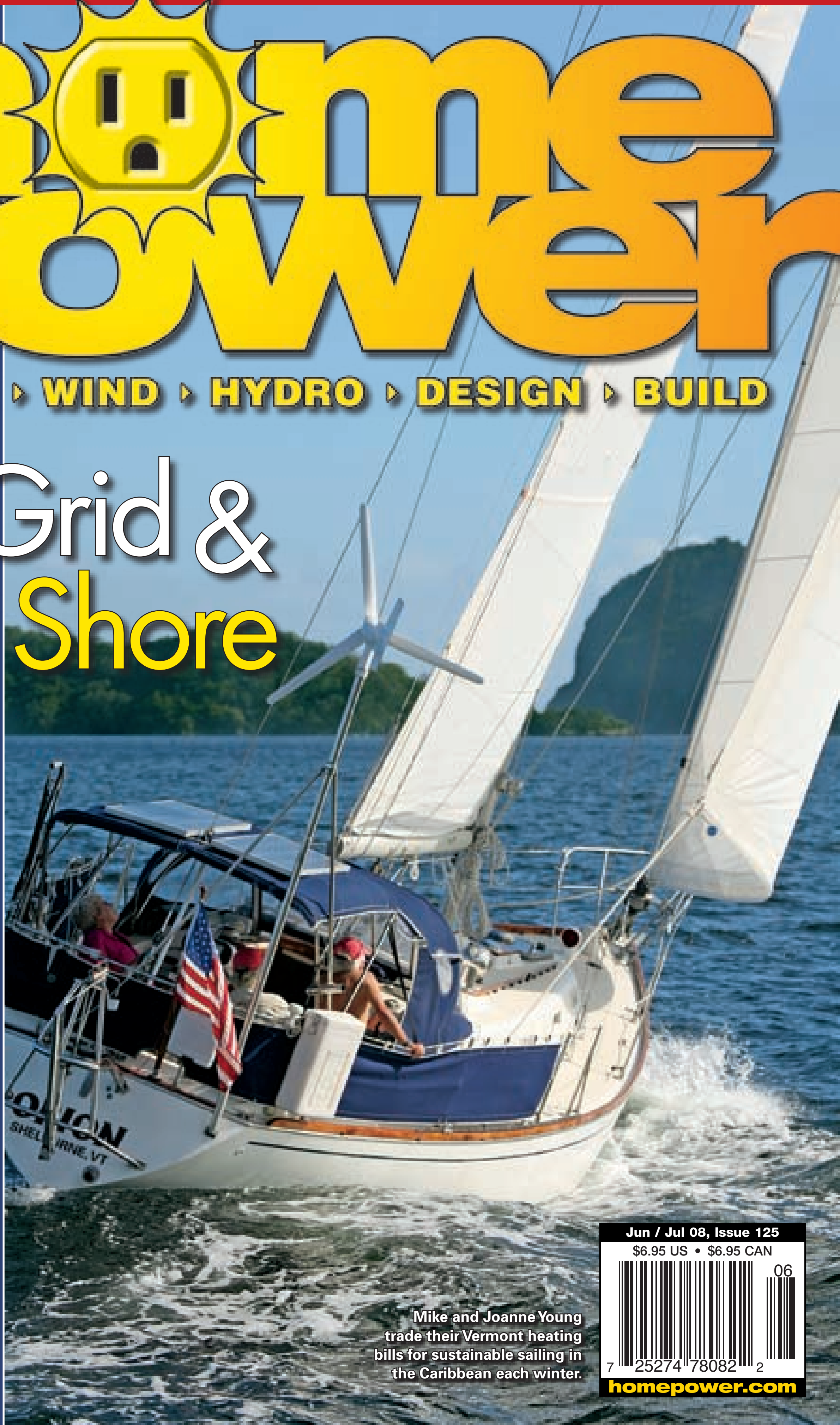

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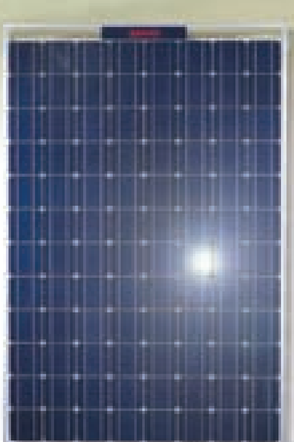

HIT® Double

BIFACIAL SOLAR PANELS!

SANYO's new **HIT® Double** bifacial solar panel captures both direct sunlight and reflected light from surrounding surfaces, generating electricity from both sides of the panel simultaneously. **HIT Double** can increase the amount of electricity produced by up to 30%* compared to single-sided HIT panels. With high kWh performance, **HIT Double** is the perfect choice to maximize rebates for projects that receive performance based incentives. Enjoy new possibilities with **HIT Double** including carports, BIPV, awnings, fences, trellises, walkways, canopies, deck coverings and more.

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